Museums
QH
1
A5

The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

Contents

Ecological Relationships of the Mammals of the Bird Creek Region, Northeastern Oklahoma—*W. Frank Blair* 473

Wildlife Mortality on Iowa Highways—*Thomas G. Scott* 527

Additional Notes on Birds of Lake Maxinkuckee Region—*Samuel E. Perkins, III* 540

A Study of the Radulae of Snails of the Family Pleuroceridae—*Samuel Wilbur Howe* 549

North American Spiders of the Genus Agroeca—*B. J. Kaston* 562

Four New Arthropods from New England—*Arthur Paul Jacot* 571

Parasites of Some Minnesota Cricetidae and Zapodidae, and a Host Catalogue of Helminth Parasites of Native American Mice—*Arnold B. Erickson* 575

Ectoparasitic Trematodes of Puget Sound Fishes-Acanthocotyle—*Kelshaw Bonham* and *John E. Guberlet* 590

Studies on Gill Trematodes from Oklahoma Fishes—*Aaron Seamster* 603

A Description of Cercaria raiacauda n.sp.—*Gerald M. Steelman* 613

Scioto River Forms of Chrysococcus—*James B. Lackey* 619

Preliminary Report of the Phytoplankton of the Gulf of Maine—*Lois C. Lillick* 624

Comparison of the Environment and Certain Physiological Activities of Alfalfa and Prairie Vegetation—*Morton T. Fredericksen* 641

The Effect of the Moisture-Retaining Capacity of Soils on Forest Succession in Itasca Park, Minnesota—*Lucille Lora Kelt* 682

The Flowering Plants of the Wichita Mountains Wildlife Refuge—*Cletis T. Eskew* 695

A Morphological Study of the Leaf and Tendril of Passiflora caerulea—*Virginia B. Gangstad* 704

Note on a Lepidophyte Strobilus Containing Large Spores, from Braidwood, Illinois—*Chester A. Arnold* 709

Notes and Discussion:
Pituophis and Scaphiopus in Indiana—*Paul L. Swanson* 713
Sectional Issuance of Biological Abstracts 714

Book Reviews 716

Vol. 20 NOVEMBER, 1938 No. 3

EDITORIAL STAFF

THEODOR JUST,.....*Botany (Ecology, Taxonomy)*
Editor, University of Notre Dame

CARROLL LANE FENTON,.....*Invertebrate Paleontology*
Washington, D. C.

JOHN HOBART HOSKINS,.....*Botany (Morphology, Paleobotany)*
University of Cincinnati, Cincinnati, Ohio

REMINGTON KELLOGG,.....*Vertebrate Paleontology and Zoology*
U. S. National Museum, Washington, D. C.

MARCUS WARD LYON, JR.,.....*Mammalogy*
South Bend, Indiana

GEORGE WILLARD MARTIN,.....*Mycology*
State University of Iowa, Iowa City, Iowa

FRANCIS JOSEPH WENNINGER, C.S.C.,.....*Invertebrate Zoology*
University of Notre Dame

NOTE:—THE AMERICAN MIDLAND NATURALIST, published from the biological laboratories of the University of Notre Dame, is primarily, though not exclusively devoted to the Natural History of the Middle West. A wide selection of papers on botany, paleontology and zoology is published in bi-monthly issues, six of which make up a volume.

Fifty reprints will be furnished free of charge to contributors. Additional reprints should be ordered when proof is returned and may be had at cost price. Authors are requested to submit abstracts with their manuscripts.

The following numbers are out of print: vol. 2, (1-3, 8-10); vol. 3, (1-3, 5-12) index, title page; vol. 4, (1-7) index, title page; vol. 6, (5, 8) index, title page; vol. 9, (9); vol. 10, index, title page; vol. 11, (1). All others available, 30 cents per copy. Complete volumes: $3.00; volumes 7, 13, and 14, $1.50 each; vol. 15 $2.00, single issues 35 cents; vol. 16 $3.00, single issues 50 cents; vol. 17 $4.50, part 1 $2.00, nos. 2-6 50 cents each; vol. 18 $3.00, single issues 50 cents; vol. 19 $2.50, vol. 20 $2.50, single issues $1.00.

Exchanges for journals, special volumes or duplicate books, and specimens, should be arranged directly through the editorial office at the University of Notre Dame, where subscriptions also are received. Offers should accompany request for exchange.

For citation use this abbreviation: *Amer. Midl. Nat.*

Entered as second-class matter at Notre Dame, Indiana. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

The American Midland Naturalist

Published Bi-Monthly by The University of Notre Dame, Notre Dame, Indiana

VOL. 20 NOVEMBER, 1938 No. 3

Ecological Relationships of the Mammals of the Bird Creek Region, Northeastern Oklahoma*

W. Frank Blair

CONTENTS

	PAGE
INTRODUCTION	473
ACKNOWLEDGMENTS	474
REGION STUDIED	474
ECOLOGICAL ASSOCIATIONS	476
Oak—hickory Association	478
Ravine Forest Association	479
Oak—elm Association	481
Aquatic and Littoral Associations	483
Sedge Marsh Association	485
Buttonbush Swamp Association	486
Pin Oak Swamp Association	486
Weed Association	487
Lowland Thicket Association	488
Grama—beardgrass Association	489
Plum Thicket Association	490
Sumac—grama Association	491
Bluejoint—switchgrass Association	493
ANNOTATED LIST OF MAMMALS	494
EFFECTS OF DROUGHT	508
POPULATION STUDIES	511
GENERAL ECOLOGICAL RELATIONSHIPS OF THE REGION	515
ECOLOGICAL DISTRIBUTION OF THE MAMMALS	518
SUMMARY	524
REFERENCES	526

Introduction

The broad ecotone between the deciduous forest of eastern North America and the grasslands of the Great Plains is of particular ecological and zoogeographical interest. In northeastern Oklahoma, biotic communities of the eastern deciduous forest, of the tall-grass prairies, and of the Great Plains grasslands exist side by side in this transition area.

Many species of animals reach the eastern or western limits of their ranges in the transition area, though a number of wide-ranging species occur in biotic areas on both sides of the ecotone. The transition area between the forest and grassland, therefore, lends itself to a study of some of the factors that govern the distribution of animals.

* A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the University of Michigan.

An ecological field study of the Bird Creek region, which lies in the transition area between forest and grassland in northeastern Oklahoma, was conducted during the field seasons of 1935, 1936, and part of 1937. This study involved the determination of the ecological communities of the region and their relationships to the ecological communities of the nearby biotic areas. Special attention was given to the species of mammals present in each community and their relative abundance.

Acknowledgments

I am indebted to Lee R. Dice for the supervision of my work and to William H. Burt for many helpful suggestions during the course of the study. O. W. Letson is responsible for the identification of the plants discussed herein and has contributed notes on his observations of several species of mammals. Unpublished notes were kindly contributed by H. D. Chase, who permitted me to examine specimens collected by myself previous to 1935, now in the collection of the Department of Zoology, University of Tulsa. Valuable specimens have been donated by A. P. Blair and P. F. Blair, Jr. Hugh S. Davis contributed specimens and unpublished notes. The Oklahoma Game and Fish Commission issued the necessary collecting permits through its chairman, C. F. Sykes. I am indebted to H. H. T. Jackson of the United States Bureau of Biological Survey; C. C. Sanborn, Curator of Mammals, Field Museum of Natural History; and C. D. Bunker, Curator of Birds and Mammals, University of Kansas Museum, for the loan of specimens in their charge. Climatological data were kindly furnished by the United States Weather Bureau. Valuable library assistance was given by F. R. Harrell.

Region Studied

The area studied comprises 112 square miles in Tulsa and Rogers counties, Oklahoma. Approximately two-thirds of it lie in the former and one-third in the latter county. The area includes the lower Bird Creek valley, a small portion of the valley of the Verdigris River, into which Bird Creek flows, and the adjacent uplands. Coal Creek and Mingo Creek are tributaries of Bird Creek, and Spunky Creek flows into the Verdigris River a short distance below the mouth of Bird Creek. The area studied henceforth will be designated as the Bird Creek region.

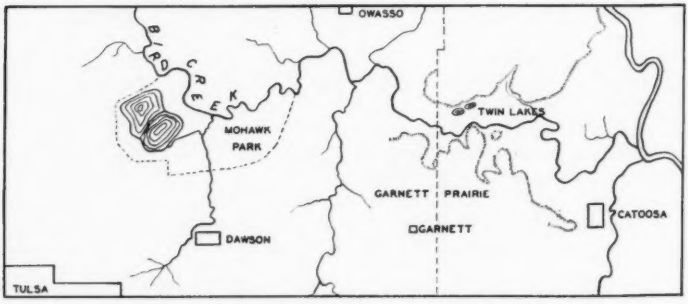


Fig. 1. Sketch map of the Bird Creek region, northeastern Oklahoma.

The entire area lies in the Prairie Plains physiographic region of Snider (1917, 81 and map opposite p. 59). The region is mostly a level, prairie plain, broken in places by low escarpments (Oklahoma Geological Survey, 1930, 628). The flood-plains of the streams generally are broad, and the streams are intrenched, with steep, muddy banks. In the Garnett and Twin Lakes areas the lowland and upland are separated by stony bluffs and steep-walled ravines.

The surface geology of the Bird Creek region has been described and mapped by the Oklahoma Geological Survey (1930, 629, map No. L; 271 and map No. XXVI). Sandstones and shales of the Nowata and Coffeyville formations are exposed in the western half of the area. The Oologah limestone is exposed in a strip bounded on the west by a line drawn approximately north and south through Owasso. In the northern part of the Bird Creek region it extends eastward to the narrow outcrop of Labette shale adjacent to the Verdigris River flood-plain. In the southern part of the region there is an outcrop of the Labette shale and a narrow outcrop of the Fort Scott limestone between the Oologah formation and the Cherokee shale that borders the valley of the Verdigris River. Erosion of the Oologah formation has produced the bluffs and ravines in the Garnett and Twin Lakes areas.

The average annual temperature of the region, furnished by the United States Weather Bureau, is 60.1° F. (average of 26 year record at Tulsa extending through 1930, 21 year record at Broken Arrow about 8 miles south of the region, and 12 year record at Claremore a similar distance east of the region). The average annual rainfall, computed similarly, is 38.5 inches. Thirty-six per cent of the rainfall comes in April, May, and June. The average length of the growing season is 214 days. The prevailing wind direction is south in every month except February and December, when it is north. The average wind velocity is 11.7 miles per hour at Broken Arrow. The average relative humidity at this station is 85 percent at 7 a. m. and 61 per cent at 12:30 p.m.

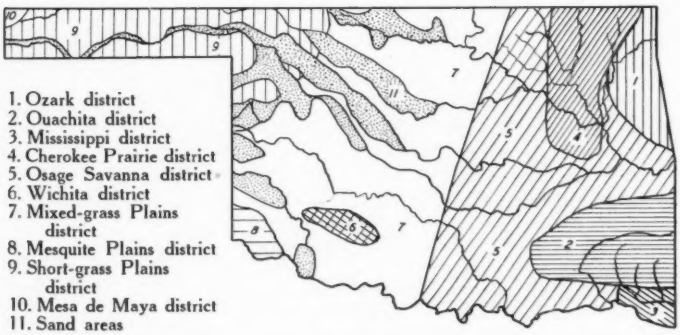


Fig. 2. Map of the biotic districts in Oklahoma (after Blair and Hubbell).

The Bird Creek region lies in the Cherokee Prairie biotic district, which extends northward into Kansas and eastward to the base of the Ozarks (Blair and Hubbell, 1938). The Osage Savanna biotic district extends to within about 2 miles of the western edge of the region *(op. cit.)*. Both the Cherokee Prairie and the Osage Savanna are a part of the deciduous forest—grassland ecotone. Forests are present in the Bird Creek region in the stream valleys and in ravine complexes, and sometimes there is a narrow belt of forest on the level upland adjacent to the ravines or stream valleys. Most of the level upland is occupied by a tall-grass type of prairie on shale and sandstone soils, and a sub climax mixed prairie on the Oologah limestone.

A general survey of the mammals of the region was made in the summer of 1935, from June 20 to September 15, and at the same time the principal plant communities were determined. In the summer of 1936, from June 1 to September 10, the distribution of the mammals in the plant communities was worked out, and an attempt was made to obtain a measure of the abundance of some of the smaller species through the use of trapping quadrats and measured lines. Plant lists for the communities also were prepared during this time. Five days were spent in Woods and Major counties; 5 days in Osage County; and 10 days in Cherokee and Adair counties obtaining specimens and data for comparison with those from the Bird Creek region. Two weeks, from June 15 to June 30, 1937, were spent in making additional notes on the plants of the region and in observing the effects on them of the drought of 1936. I was accompanied during these trips by Fern Ann Blair, and a part of the time A. K. Leatherwood, A. P. Blair, and P. F. Blair, Jr., were members of the party. The last week of August, 1937, was spent in northern Oklahoma with T. H. Hubbell, and notes were made on the vegetation of the Bird Creek and adjoining regions.

The principal stations in the Bird Creek region at which field work was done were: (1) the Garnett area including the Garnett prairie, Garnett ravines, and the lowlands of Bird Creek in that region (2) the Twin Lakes area across Bird Creek from the Garnett area and (3) Mohawk Park where most of the work was done in the North Lake wilderness area and the bird and wildflower sanctuary (Fig. 1).

During the field study 588 specimens of mammals were prepared, and these are deposited in the collection of the Museum of Zoology, University of Michigan. About 100 specimens of mammals were obtained by casual collecting in the region during 1932, 1933, and 1934, and numerous field notes were made. These specimens are in the collection of the Department of Zoology, University of Tulsa.

Ecological Associations

The transition in Oklahoma from the deciduous forest which occupies most of eastern North America (Weaver and Clements, 1929, 451) to the grasslands of the Great Plains occurs in an area about 100 miles wide. In Oklahoma, the Great Plains extend eastward across approximately the west-

ern half of the state to the eastern boundary proposed by Bollinger (1925, 123), and the grasslands of the Great Plains in Oklahoma have been described by Blair and Hubbell (1938). The transition area, in northeastern Oklahoma, lies between the Ozark district of the eastern deciduous forest and the Mixed-grass Plains district of the Great Plains grasslands (Fig. 2). The Bird Creek region, being centrally located in this transition area, is near the line at which theoretically the biota of the eastern deciduous forest and that of the Great Plains grasslands should be of equal importance. This theoretical line is of little significance, because edaphic factors control the local occurrence of ecological associations in this transition area, and associations of the eastern deciduous forest and those of the Great Plains grasslands occur side by side in many places. This transition area is occupied partly by associations of the eastern deciduous forest and partly by those of the Great Plains grasslands and should be considered an ecotone between the eastern deciduous forest and the Great Plains grasslands.

Fig. 3. Oak—hickory association in Garnett area, Bird Creek region, northeastern Oklahoma, June 27, 1937. Note open nature of forest and heavy, herbaceous cover in foreground.

The ecological associations of the Bird Creek region are related to the typical associations of 3 major biotic areas. The oak—hickory, ravine forest, and oak—elm associations resemble typical associations of the eastern deciduous forest as represented in the Ozark biotic district (Blair and Hubbell, 1938). The bluejoint—switchgrass association is closely related to the typical association of the tall-grass prairies, that extends southwestward from Illinois and Indiana (Clements, 1920, 131). The grama—beardgrass association resembles in its essential features the typical association of the Mixed-grass Plains district (Blair and Hubbell, *op. cit.*), which comprises the eastern half of the Great Plains in Oklahoma. The sumac—grama association resembles, in some respects, associations of the eastern deciduous forest, and in some respects those of the Mixed-grass Plains, but it is most closely related to the latter.

The term association, as it is employed here, refers to all of the plants and animals occurring together in a relatively stable environment. The order of succession has not been determined, so the terminology of Clements is not used.

Oak—hickory association.—The level upland adjacent to the ravine systems of the Garnett area south of Bird Creek and of the Twin Lakes area north of Bird Creek is occupied by a sparse oak—hickory forest. This forest is as much as several hundred yards wide where best developed, and it is absent from those places where the grassland extends to the rim-rock of the ravines. Generally there are abundant outcrops of limestone within the boundaries of this association, and limestone boulders are present over much of the area. The trees are limited almost entirely to 2 species, the blackjack oak *(Quercus marilandica)* and black hickory *(Carya buckleyi)*, although scattered individuals of other species, principally oaks, are present. In some places almost pure stands of the hickory are to be found. Most of the trees of the association are less than 8 inches d. b. h. (diameter breast high), and the largest individuals seldom exceed 15 inches. They are gnarled and stunted in their form of growth, apparently because of rapid drainage and moisture deficiency in the thin, limestone soil on which the association occurs.

The most abundant low shrub is the coral berry *(Symphoricarpos orbiculatus)*, and the most conspicuous large shrub is the smooth sumac *(Rhus glabra)*. The open character of the forest permits the existence of numerous herbs, many of which are grassland rather than forest species. The most conspicuous of these are the side-oats grama *(Bouteloua curtipendula)*, panic grass *(Panicum* sp.), buffalo grass *(Buchloë dactyloides)*, silver beardgrass *(Andropogon saccharoides)*, wild bergamot *(Monarda fistulosa)*, black eyed susan, (*Rudbeckia hirta*), skullcap (*Scutellaria* sp.), and ironweed (*Vernonia* sp.). Over small areas greenbriers (*Smilax* sp.), poison ivy *(Rhus toxicodendron)*, and frost grape *(Vitis cordifolia)* intertwine near the ground or on low shrubs to form a heavy cover.

Other plants identified:

Aster patens	*Opuntia humifusa*
Bumelia lanuginosa	*Paspalum* sp.
Diospyros virginiana	*Quercus muhlenbergii*
Euphorbia sp.	*Quercus shumardii*
Festuca octoflora	*Rhus canadensis*
Fraxinus americana	*Rhus copallina*
Hordeum pusillum	*Schedonnardus paniculatus*

In general aspect the oak—hickory association is rather dry and barren. There is no appreciable accumulation of leaf mold and the soil is baked hard during the dry months. The shrubs are too scattered to offer very much cover for small mammals. In the summer much of the shrub foliage, particularly that of the coral berry and smooth sumac, is destroyed by grasshoppers.

Mammals of the oak—hickory association	Records
Didelphis virginiana virginiana	1
Sciurus carolinensis carolinensis	Numerous
Sciurus niger rufiventer	Numerous
Peromysus leucopus noveboracensis	18
Neotoma floridana baileyi	5
Sylvilagus floridanus alacer	5

The wood-mouse *(Peromyscus leucopus)* probably is the most abundant mammal of this association. The gray-squirrel *(Sciurus carolinensis)* and the fox-squirrel *(Sciurus niger)* are other important semi-arboreal species. The cottontail *(Sylvilagus floridanus)* is a conspicuous terrestrial mammal, and the woodrat *(Neotoma floridana)* occurs near rock outcrops. The opossum *(Didelphis virginiana)* is rare in this association.

Fig. 4. Section of rim-rock in Garnett ravines, Bird Creek region, northeastern Oklahoma. Oak—hickory association in background.

Ravine forest association.—The Garnett ravines and those in the Twin Lakes area are narrow, steep-walled ravines cut into the limestone strata underlying the region. Around the edges of the ravines and forming a part of their walls, the limestone outcrops to form the rim-rock (Fig. 4). At the head of each ravine there generally is a drop of 5 or 6 feet from the level of the adjacent upland to the stream bed in the floor of the ravine. The stream beds are dry most of the year, but there is a permanent trickle of water in one of the Garnett ravines. Some of the ravines have travertine deposits in the process of formation. A few more or less permanent springs issue from the sides of the ravines, and in one place there is a small cave at the base of the rim-rock. The slopes of the ravines are littered with

limestone fragments, and large masses of limestone have broken from the rim-rock and rolled down the slopes.

The two ravine complexes are occupied by forest types that differ distinctly from those of the adjacent level upland and flood-plain. In the Garnett ravines the characteristic trees are the sugar maple *(Acer saccharum)*, chinquapin oak *(Quercus muhlenbergii)*, spotted oak *(Quercus shumardii)*, American elm *(Ulmus americana)*, and black hickory *(Carya buckleyi)*. The most abundant shrubs on the slopes of the Garnett ravines are the coral berry *(Symphoricarpos orbiculatus)*, roughleaf dogwood *(Cornus asperifolia)*, blackhaw *(Viburnum rufidulum)*, hawthorn *(Crataegus* sp.), and wooly buckthorn *(Bumelia lanuginosa)*. The bladdernut *(Staphylea trifolia)* occurs in moist, protected pockets. The smoke tree *(Rhus cotinoides)* is abundant on the slopes and occurs on the rim-rock, where it is associated with the fragrant sumac *(Rhus canadensis)*. The columbine *(Aquilegia canadensis)* and numerous saxicolous ferns grow on the rim-rock. Characteristic herbs of the ravine slopes are the Dutchman's breeches *(Dicentra cucullaria)*, white dogtooth violet *(Erythronium albidum)*, Solomon's seal *(Polygonatum commutatum)*, and the green dragon *(Arisaema dracontium)*. The yellow dogtooth violet *(Erythronium americanum)* grows at the base of a moist, north-facing bluff near the mouth of Bird Creek.

The ravines of the Twin Lakes area are characterized by the dominance of the spotted and chinquapin oaks. A few trees of the scarlet oak *(Quercus coccinea)*, which is absent from the Garnett ravines, grow in these ravines. The most abundant shrubs are the roughleaf dogwood, fragrant sumac, and the smooth sumac *(Rhus glabra)*. Wherever trees are lacking on the ravine slopes in either area the beardgrass *(Andropogon* sp.), side-oats grama *(Bouteloua curtipendula)*, and numerous other herbs are present.

Other plants identified:

Carya cordiformis
Celtis laevigata
Celtis occidentalis
Cercis canadensis
Croton monanthogynus
Diospyros virginiana
Elymus virginicus
Fraxinus americana
Gleditsia triacanthos
Ilex decidua
Juglans nigra
Lespedeza sp.
Mentzelia oligosperma
Morus rubra
Prunus mexicana
Psoralea tenuifolia
Rhus copallina
Rhus toxicodendron
Rosa setigera
Sapindus drummondi
Ulmus fulva
Zanthoxylum americanum

Many of the plants of the ravines are present also in the flood-plain forest or in the various communities of the level upland, but the sugar maple, smoke tree, bladdernut, and some of the herbaceous mesophytes of the Garnett ravines are confined to the ravines. The differences between the ravine forest and the forests on adjacent areas apparently are due to differences in slope and exposure, and the most mesic plants are found only on north-facing slopes. The plants of the Garnett ravines, which are predominantly north-

facing, are more unlike those of the adjacent flood-plain than are the plants of the Twin Lakes ravines, in which the exposure generally is southern.

Mammals of the ravine forest association.	Records
Scalopus aquaticus intermedius	Burrows
Pipistrellus subflavus subflavus	4
Mephitis mephitis mesomelas	1
Sciurus carolinensis carolinensis	2
Sciurus niger rufiventer	1
Peromyscus leucopus noveboracensis	36
Peromyscus boylii attwateri	21
Sigmodon hispidus texianus	1
Neotoma floridana baileyi	11
Sylvilagus floridanus alacer	6

The brush-mouse *(Peromyscus boylii)* and woodrat *(Neotoma floridana)* are associated with the rim-rock, and to a lesser extent with the rock masses on the ravine slopes. The striped skunk *(Mephitis mephitis)* and cottontail *(Sylvilagus floridanus)* find refuge in crevices in the rim-rock. The mole *(Scalopus aquaticus)* occurs in limited areas of deeper soil on the ravine floor. The pipistrelle *(Pipistrellus subflavus)* inhabits a cave in the outcropping limestone. The cotton-rat *(Sigmodon hispidus)* is a rare inhabitant of situations with heavy cover. The gray-squirrel *(Sciurus carolinensis)* fox-squirrel *(Sciurus niger)*, and wood-mouse *(Peromyscus leucopus)* are semi-arboreal forms that are associated with the trees in the ravines.

Oak—elm association.—The Bird Creek flood-plain is from 2 to 4 miles wide in the Mohawk Park area and merges gradually with the adjacent uplands. The flood-plain narrows to a width of about three-fourths of a mile at a point about one-half mile above the mouth of Mingo Creek, and it averages from one-half to one mile in width in the Twin Lakes area. It is about 5 miles wide at the junction of Bird Creek and the Verdigris River. The soils of the flood-plain are dark and heavy, being derived largely from limestones and shales. The flood-plain rarely is flooded, as Bird Creek is deeply intrenched in this region and leaves its banks only in times of heavy and continued rainfall. For about 10 years most of the Mohawk Park flood-plain has been protected by a dike from flooding by Bird Creek. The most severe flood of recent years occurred in the spring of 1935, when practically all of the flood-plain, except that protected by the dike in Mohawk Park, was inundated for several weeks. Parts of Mohawk Park have been ungrazed and protected from fire for about 10 years.

The flood-plains of Bird Creek and its tributaries are occupied by an oak—elm forest except where the land has been cleared or where minor communities exist surrounded by the mature forest. The oak—elm association includes those parts of the flood-plain on which the oak—elm forest exists undisturbed or from which it has not been completely removed. The principal dominants of this forest are the spotted oak *(Quercus shumardii)*, slippery elm *(Ulmus fulva)*, American elm *(Ulmus americana)*, and 2 hackberries *(Celtis occidentalis* and *C. laevigata)*. Trees of somewhat less importance are the bur oak *(Quercus macrocarpa)*, pin oak *(Quercus palustris)*, and pecan *(Carya pecan)*. Most of the lowland forest has been cut

over. The thinning of the forest has been followed by an increase in the abundance of shrubby and herbaceous vegetation, so that in much of the forest there is an alternation of large trees with weed patches, shrub thickets, or clumps of young trees.

Fig. 5. Oak—elm association in Mohawk Park, Bird Creek region, northeastern Oklahoma, June 27, 1937. A situation that suffered little from the drought of 1936. Note density of shrub layer.

The high shrub layer of the forest is formed by the dwarf sumac *(Rhus copallina)*, roughleaf dogwood *(Cornus asperifolia)*, swamp holly *(Ilex decidua)*, blackhaw *(Viburnum rufidulum)*, pricklyash *(Zanthoxylum americanum)*, common elder *(Sambucus canadensis)*, spicebush *(Benzoin aestivale)*, and others. The coral berry *(Symphoricarpos orbiculatus)*, a blackberry *(Rubus andrewsianus)*, and the prairie rose *(Rosa setigera)* are the chief constituents of the low shrub layer. Numerous vines climb over the shrubs and trees. These include the bittersweet *(Celastrus scandens)*, two grapes *(Vitis cordifolia* and *V. cinerea)*, trumpet creeper *(Tecoma radicans)*, poison ivy *(Rhus toxicodendron)*, woodbine *(Psedera quinquefolia)*, Carolina moonseed *(Cocculus carolinus)*, and greenbrier (*Smilax* sp.).

The more conspicuous herbs are the green dragon *(Arisaema dracontium)*, Solomon's seal *(Polygonatum commutatum)*, ironweed *(Vernonia altissima)*, coneflowers *(Rudbeckia triloba* and *R. subtomentosa)*, trumpet weed *(Eupatoreum purpureum)*, goldenrod *(Solidago serotina)*, and elephant's foot *(Elephantopus carolinianus)*. Numerous grasses are present among the herbs on the forest floor, but they are nowhere dominant. The grasses include the Virginia wild rye *(Elymus virginicus)*, broadleaf uniola *(Uniola latifolia)*, switchgrass *(Panicum virgatum)*, bluejoint *(Andropogon furcatus)*, Indiangrass *(Sorghastrum nutans)*, purpletop *(Triodia flava)*, and fringed brome *(Bromus ciliatus)*.

Other plants identified:

Actinomeris alternifolia
Carya cordiformis
Cercis canadensis
Cirsium lanceolatum
Crataegus sp.
Desmodium grandiflorum
Desmodium illinoense
Diospyros virginiana
Eupatorium coelistinum
Eupatorium urticaefolium
Euphorbia heterophylla
Fraxinus americana
Fraxinus pennsylvanica var. *lanceolata*
Gleditsia triacanthos
Gymnocladus dioica
Juglans nigra
Morus rubra
Physalis longifolia
Prunus mexicana
Prunus serotina
Rosa setigera
Solanum carolinense

There is a good accumulation of leaf-mold on the forest floor except where the forest repeatedly has been burned. Logs in all stages of decomposition litter the ground in many places.

Mammals of the oak—elm association.	Records
Didelphis virginiana virginiana	2
Scalopus aquaticus intermedius	11
Blarina brevicauda carolinensis	3
Lasiurus borealis borealis	1
Procyon lotor hirtus	Tracks
Mustela vison mink	2
Spilogale interrupta	1
Mephitis mephitis mesomelas	Signs
Sciurus carolinensis carolinensis	Numerous
Sciurus niger rufiventer	Numerous
Glaucomys volans saturatus	3
Peromyscus leucopus noveboracensis	29
Sigmodon hispidus texianus	8
Neotoma floridana baileyi	2
Pitymys nemoralis	20
Sylvilagus floridanus alacer	7
Sylvilagus aquaticus aquaticus	5

The wood-mouse *(Peromyscus leucopus)*, gray-squirrel *(Sciurus carolinensis)*, and fox-squirrel *(Sciurus niger)* are the most abundant semi-arboreal mammals in this association. The woodrat *(Neotoma floridana)* nests in trees here. Other semi-arboreal forms are the flying-squirrel *(Glaucomys volans)*, red bat *(Lasiurus borealis)*, opossum *(Didelphis virginiana)*, and raccoon *(Procyon lotor)*. The mole *(Scalopus aquaticus)* and pine vole *(Pitymys nemoralis)* are among the most abundant small mammals of the forest floor. The Carolina shrew *(Blarina brevicauda)* is another terrestrial species. The cottontail *(Sylvilagus floridanus)*, swamp-rabbit *(Sylvilagus aquaticus)*, and cotton-rat *(Sigmodon hispidus)* frequent situations in which there is heavy cover. The striped skunk *(Mephitis mephitis)*, spotted skunk *(Spilogale interrupta)*, and mink *(Mustela vison)* are wide-ranging predators in this association.

Aquatic and littoral associations.—One of the minor associations of the region is that existing on mud flats along the streams and around some of the ponds. Bird Creek and its tributaries flow through intrenched channels, and the stream banks generally are steep and muddy. There are, however,

some mud and gravel flats along Bird Creek which become quite extensive during the dry months of summer. The principal vegetation of these areas is formed by the smartweed *(Polygonum* sp.*)* and black willow *(Salix nigra)*. These plants grow on the steep, mud banks of the streams. Other stream bank plants are the cottonwood *(Populus deltoides)*, sycamore *(Platanus occidentalis)*, and silver maple *(Acer saccharinum)*.

Fig. 6. Oak—elm association in Mohawk Park, Bird Creek region, northeastern Oklahoma, June 27, 1937. In foreground, note heavy cover of *Uniola latifolia* and various mesophytes.

The aquatic association includes the water of the ponds and streams in the region. The larger ponds on the Bird Creek flood-plain contain water except in the very dryest summers. Two of the largest of the ponds are known as the Twin Lakes and lie north of Bird Creek, opposite the Garnett area. All except the deeper parts of these ponds are normally occupied by a dense growth of the American lotus *(Nelumbo lutea)*. The ponds are fringed by the buttonbush *(Cephelanthus occidentalis)*, swamp holly *(Ilex decidua)*, black willow, and green ash *(Fraxinus pennsylvanica* var. *lanceolata)*. The cattail *(Typha latifolia)* and primrosewillow *(Jussiaea diffusa)* are conspicuous plants that grow in many of the ponds and on the mud just above the water line.

Mammals of the aquatic and littoral associations.	Records
Lasiurus borealis borealis	1
Procyon lotor hirtus	Tracks
Mustela vison mink	1
Ondatra zibethica cinnamomina	5
Sylvilagus aquaticus aquaticus	Numerous

The red bat *(Lasiurus borealis)* feeds in the air over these associations and occasionally touches the surface of the water either to drink or to capture insects. The muskrat *(Ondatra zibethica)* burrows in the stream and pond

banks. The swamp-rabbit *(Sylvilagus aquaticus)* ranges along the littoral zone from areas of heavier cover and occasionally enters the water. The raccoon *(Procyon lotor)* feeds along the banks of the stream and ponds. The mink *(Mustela vison)* frequents the littoral zone and often enters the water.

Sedge marsh association.—Small flood-plain ponds in the Bird Creek region often are surrounded by a belt of sedges. In summer the smaller and more shallow of these ponds dry up, so that there remains an expanse of dry, sun-cracked earth surrounded by a heavy growth of sedges. The barren centers of such dry pond areas seldom support any vegetation except a few scattered smartweeds (*Polygonum hydropiperoides* and others). The belt of sedges is formed by *Carex lupulina* and other species of *Carex*. These sedges form a dense ground cover because of their rank growth and because of the accumulation of dead stems beneath the growing plants. The sedges in these areas remain green during even the dryest summers.

Mammals of the sedge marsh association.	Records
Peromyscus leucopus noveboracensis	4
Sigmodon hispidus texianus	40
Sylvilagus floridanus alacer	1
Sylvilagus aquaticus aquaticus	Numerous

The cotton-rat *(Sigmodon hispidus)* is the most abundant mammal of this association. The swamp-rabbit *(Sylvilagus aquaticus)* is concentrated here, and the cottontail *(Sylvilagus floridanus)* ranges through the area. The

Fig. 7. Bird Creek in Garnett area, Bird Creek region, northeastern Oklahoma, showing aquatic and littoral associations. Note black willow zone in middle foreground, and cottonwoods and silver maples in far background (Photograph by H. S. Davis).

wood-mouse *(Peromyscus leucopus)* ranges into this association from the oak—elm association, but it probably does not make its home here.

Buttonbush swamp association.—The buttonbush *(Cephalanthus occidentalis)* occupies poorly drained areas on the flood-plains of the Bird Creek system. Water usually stands in these situations during the winter and spring and disappears in the summer. The buttonbushes grow sufficiently close together that the upper branches of adjacent bushes generally meet and thoroughly shade most of the ground floor. This shade and the presence of water during a part of the year result in an almost total lack of ground cover in most of the area of the buttonbush swamps. Where the shading

Fig. 8. Sedge marsh association in Mohawk Park, Bird Creek region, northeastern Oklahoma, August, 1936. Note density of the sedge cover.

is not complete a smartweed *(Polygonum hydropiperoides)* occurs. Occasional openings in the thickets are occupied by sedges (*Carex lupulina* and a smaller, unidentified species). The black willow *(Salix nigra)* often grows around the margins of the swamps.

Mammals of the buttonbush swamp association.	Records
Peromyscus leucopus noveboracensis	3
Sigmodon hispidus texianus	2
Sylvilagus floridanus alacer	Numerous
Sylvilagus aquaticus aquaticus	Numerous

The cotton-rat *(Sigmodon hispidus)* is scarce in the sparse cover of this association. The swamp-rabbit *(Sylvilagus aquaticus)* and cottontail *(Sylvilagus floridanus)* range through the area. The wood-mouse *(Peromyscus leucopus)* apparently enters from the oak—elm association.

Pin oak swamp association.—Poorly drained areas on the Bird Creek flood-plain sometimes are occupied by an almost pure stand of pin oak *(Quercus*

palustris), with which is mixed a few bur oaks *(Quercus macrocarpa)*. The trees grow close together and shade most of the forest floor. The pin oaks are small and seldom exceed 10 inches d. b. h. The shrub layer is almost lacking in this area and is represented only by scattered swamp holly *(Ilex decidua)* and persimmon *(Diospyros virginiana)* shrubs. The forest floor is barren of herbs except in a few slightly shaded situations where a small species of *Carex* forms a sparse cover. There are a few small seedlings of Carolina moonseed *(Cocculus carolinus)* and greenbrier (*Smilax* sp.) on the barren forest floor.

Mammals of the pin oak swamp association.	Records
Sciurus carolinensis carolinensis	Numerous
Sciurus niger rufiventer	Numerous
Peromyscus leucopus noveboracensis	1

The gray-squirrel *(Sciurus carolinensis)* and fox-squirrel *(Sciurus niger)* build leaf nests in the pin oaks. The wood-mouse *(Peromsycus leucopus)* is scarce here. The absence of terrestrial mammals probably is due to the lack of ground cover.

Weed association.—Parts of the Bird Creek flood-plain have been cleared and cultivated. If these fields are abandoned they soon are invaded by numerous weeds of which the most conspicuous are the ragweed *(Ambrosia trifida)*, a relative of the evening primrose *(Gaura biennis)*, pigweed *(Chenopodium* sp.), and the Jerusalem artichoke *(Helianthus tuberosus)*. These weeds form dense stands and often grow to 6 feet or more in height. A low, grassy cover is formed by the crab grass *(Digitaria sanguinalis)*. The stumps of the original forest trees are seldom removed from these fields, and their second-growth sprouts often form a conspicuous feature of the habitat. The trumpetcreeper *(Tecoma radicans)* and a low blackberry (*Rubus* sp.) are among the early invaders of these areas.

Other plants identified:

Erigeron canadensis
Lactuca scariola
Oenothera biennis
Rudbeckia triloba
Solanum carolinense

Most of the weeds that enter into the formation of this association have tall stems. These weeds are closely spaced and shade most of the ground beneath them, and there is very little low ground cover except that formed by the crab grass.

Mammals of the weed association.	Records
Peromyscus lecopus noveboracensis	1
Sigmodon hispidus texianus	16
Sylvilagus floridanus alacer	Numerous

The cotton-rat *(Sigmodon hispidus)* and cottontail *(Sylvilagus floridanus)* are abundant in this association. The wood-mouse *(Peromyscus leucopus)* apparently ranges here from the oak—elm association.

Lowland thicket association.—Fields on the Bird Creek flood-plain that have been abandoned for several years have become dense thickets of young trees mixed with various shrubs and weeds. The young trees are mostly the spotted oak *(Quercus shumardii)*, bitternut hickory *(Carya cordiformis)*, pecan *(Carya pecan)*, and American elm *(Ulmus americana)*. Most of the tree seedlings are less than 10 feet tall, although a few have reached 25 feet. There are many shrubby persimmons *(Diospyros virginiana)*, most of which are less than 8 feet in height. Plants that contribute chiefly to the thicket-like aspect of the area are a blackberry *(Rubus andrewsianus)*, three grapes *(Vitis cordifolia, V. vulpina,* and *V. cinerea)*, trumpet creeper *(Tecoma radicans)*, greenbrier *(Smilax* sp.), prairie rose (Rosa setigera), and the smooth and dwarf sumacs *(Rhus glabra* and *R. copallina)*. The weeds are a mixture of many species, of which the most conspicuous are the tarweed *(Grindelia squarrosa)*, Jerusalem artichoke *(Helianthus tuberosus)*, wild potato vine *(Ipomoea pandurata)*, horse mint *(Monarda fistulosa)*, coneflower *(Rudbeckia triloba)*, and ironweed *(Vernonia altissima)*.

Other plants identified:

Cercis canadensis
Cirsium lanceolatum
Cissus ampelopsis
Cocculus carolinus
Cornus asperifolia
Elymus sp.
Gleditsia triacanthos
Lespedeza sp.
Morus rubra
Panicum sp.
Rhus toxicodendron
Rubus villosus
Strophostyles helvola
Verbesina virginica

Most of the herbs have tall stems, and many of them equal the shrubs in height. These tall herbs and the shrubs are so bound together by the climbing and trailing plants, particularly the wild potato vine and trumpetcreeper, that a very dense and tangled thicket is formed. The vines and the plants on which they climb so shade the ground that it is almost entirely barren of any cover of low herbs.

Mammals of the lowland thicket association.	Records
Lasiurus borealis borealis	1
Sciurus carolinensis carolinensis	1
Sciurus niger rufiventer	1
Peromyscus leucopus noveboracensis	15
Sigmodon hispidus texianus	1
Mus musculus musculus	1
Zapus hudsonius campestris	2
Sylvilagus floridanus alacer	Numerous
Sylvilagus aquaticus aquaticus	Numerous

The gray-squirrel *(Sciurus carolinensis)* and fox-squirrel *(Sciurus niger)* build leaf nests in the highest trees. Other semi-arboreal species include the wood-mouse *(Peromyscus leucopus)*, which is common, and the red bat *(Lasiurus borealis)*. The cottontail *(Sylvilagus floridanus)* is abundant, and the swamp-rabbit *(Sylvilagus aquaticus)* occasionally ranges through the association. The cotton-rat *(Sigmodon hispidus)*, jumping-mouse *(Zapus hudsonius)*, and house-mouse *(Mus musculus)* are scarce in this area. This is the

only association in the Bird Creek region in which the jumping-mouse has been taken.

Grama—beardgrass association.—The slightly rolling uplands adjacent to the Bird Creek valley in the Twin Lakes and Garnett areas are covered with a thin mantle of soil and residual limestone fragments. This mantle generally is less than a foot in depth, and in many places the underlying Oologah limestone outcrops at the surface. The fragments vary from the size of a pea to boulders several yards in diameter. Most of the loose fragments, however, are less than a yard in diameter, and many are very thin, being only 2 or 3 inches thick. The plant cover, particularly of grasses and summer and autumn herbs, usually follows the joints in the underlying limestone. In the spring the area is covered by gaillardia *(Gaillardia pulchella)*, and the more rocky areas have a dense cover of stonecrop *(Sedum pulchellum)*. The most abundant grasses are the side-oats grama *(Bouteloua curtipendula)*, silver

Fig. 9. Grama—beardgrass association on Garnett prairie, Bird Creek region, northeastern Oklahoma, June 27, 1937. Note alternation of plant cover with limestone fragments. Ravine forest association in background. Twin Lakes prairie, visible on the skyline, lies on the opposite side of the valley of Bird Creek.

beardgrass *(Andropogon saccharoides)*, and buffalo grass *(Buchloë dactyloides)*. The last forms almost pure stands on the more xeric tops of some of the ridges. The prickly pears *(Opuntia humifusa* and *O. tortispina)* are widely distributed in the association and often form low clumps. The Missouri cactus *(Mamillaria missouriensis)* also occurs in much of the area. The blue false indigo *(Baptisia australis)*, wild alfalfa *(Psoralea tenuifolia)*, nettle *(Tragia nepetaefolia)*, lemon mint *(Monarda citriodora)*, and croton *(Croton monanthogynus)* are among the more conspicuous spring and summer herbs. The kindling weed *(Amphiachyris dracunculoides)* is the most conspicuous autumn herb. The yucca *(Yucca glauca)* is locally abundant. Small persimmon *(Diospyros virginiana)* trees are scattered over some of the slopes, and

in some situations they form open groves. Many of these trees, which seldom are more than 15 feet in height, show the effects of prairie fires.

Other plants identified:

Arenaria stricta
Asclepiodora viridis
Erysimum asperum
Linum sp.
Petalostemum purpureum
Physalis sp.
Prunus angustifolia
Talinum teretifolium
Triodia mutica

This association is one of mixed grasses and is most closely related to the grasslands of the Mixed-grass Plains and Osage Savanna biotic districts (Blair and Hubbell, 1938). Where tall grasses are present they are unable to form extensive sod because of their limitation to small pockets of deep soil between the limestone fragments. The short grasses, buffalo grass and side-oats grama, are able to exist on thin soil, so there is a mixture of clumps of tall grasses with the more extensively distributed short grasses.

The association is moderately grazed by cattle and horses. Prairie fires frequently sweep all or parts of the area in late summer and autumn. Their most notable effect is the top-killing of the persimmon saplings so that they seldom become very tall. In some instances the entire trunk is killed, and the following year a shrubby growth of sprouts grows from the base of the trunk.

Mammals of the grama—beardgrass association.	Records
Canis latrans subspecies	3
Spilogale interrupta	Numerous
Mephitis mephitis mesomelas	1
Citellus tridecemlineatus texensis	1
Perognathus hispidus spilotus	6
Reithrodontomys montanus griseus	3
Peromyscus maniculatus ozarkiarum	21
Sigmodon hispidus texianus	Numerous
Lepus californicus melanotis	8
Sylvilagus floridanus alacer	3

The plains pocket-mouse *(Perognathus hispidus)* and deer-mouse *(Peromyscus maniculatus)* are the most abundant small mammals of the grama—beardgrass association. The thirteen-lined spermophile *(Citellus tridecemlineatus)* and harvest-mouse *(Reithrodontomys montanus)* are less abundant. The cotton-rat *(Sigmodon hispidus)* occurs in this association in times of great abundance. The jackrabbit *(Lepus californicus)* and coyote *(Canis latrans)* range throughout the area, and the cottontail *(Sylvilagus floridanus)* rarely enters it from other associations. The striped skunk *(Mephitis mephitis)* lives beneath the larger limestone fragments, and the spotted skunk *(Spilogale interrupta)* ranges through the association.

Plum thicket association.—Thickets of the Chickasaw plum *(Prunus angustifolia)* occur on limestone soils, where they generally are surrounded by the grama—beardgrass association. In a few cases, however, they are surrounded by the sumac—grama association. These thickets vary in size from

a few feet to 100 or more feet in diameter. The shrubs usually are from 3 to 6 feet high and often form dense thickets. In some situations the plums are spaced openly and alternate with herbs that are typical of the grama—beardgrass association. In all of the thickets the herbs are those present in the surrounding associations. The ground cover is heavier in the plum thicket association than in the surounding grama—beardgrass association, probably because of the presence of deeper soil.

Mammals of the plum thicket association.	Records
Perognathus hispidus spilotus	2
Peromyscus maniculatus ozarkiarum	1
Sigmodon hispidus texianus	17
Sylvilagus floridanus alacer	Numerous

Fig. 10. Sumac—grama association in Garnett area, Bird Creek region, northeastern Oklahoma, June 27, 1937. Note persimmon and smooth sumac shrubs in middle foreground and heavy herbaceous cover in near foreground. Tree in left background killed by drought of 1936.

The cotton-rat *(Sigmodon hispidus)* is abundant in the heavy cover of this association. This cover probably is responsible for the frequent occurrence here of the cottontail *(Sylvilagus floridanus)*. The deer-mouse *(Peromyscus maniculatus)* and plains pocket-mouse *(Perognathus hispidus)* have burrows beneath limestone slabs in the plum thickets.

Sumac—grama association.—A mixture of grassland and forest species of plants characterizes a strip that varies in width from 100 to 400 yards along the line of contact between the oak—hickory and grama—beardgrass associations. The boundary of this area is sharply defined on the side in contact with the oak—hickory association, and on the other side this association passes gradually into the grama—beardgrass association. The sumac—grama association extends out into the grama—beardgrass association along numerous dry watercourses.

A few large, solitary trees occur in the association, but they are so widely scattered that they exert little control over the other vegetation. These trees include the bur oak *(Quercus macrocarpa)*, spotted oak *(Quercus shumardii)*, chinquapin oak *(Quercus muhlenbergii)*, and black history *(Carya buckleyi)*. Most of the area is covered by an open thicket of shrubby persimmons *(Diospyros virginiana)* and smooth sumac *(Rhus glabra)*. The coral berry *(Symphoricarpos orbiculatus)* contributes to the formation of the thicket, and the fragrant sumac *(Rhus canadensis)* grows in scattered clumps.

The herbaceous cover is heavier here than in the grama—beardgrass association, but essentially the same species of plants are present. There is the same interruption of the ground cover by limestone fragments that characterizes the grama—beardgrass association. The larger grasses, including the silver beardgrass *(Andropogon saccharoides)* and side-oats grama *(Bouteloua curtipendula)*, predominate, and the smaller buffalo grass *(Buchloë dactyloides)* is scarce in this association. Along the dry watercourses much of the grass cover is formed by tumblegrass *(Schedonnardus paniculatus)*. Many prairie species contribute to the formation of the herbaceous cover. The most important of these are gaillardia *(Gaillardia pulchella)*, lemon mint *(Monarda citriodora)*, blue false indigo *(Baptisia australis)*, and wild alfalfa *(Psoralea tenuifolia)*. Forest species that occur in this association include the woodbine *(Psedera quinquefolia)*, Carolina moonseed *(Cocculus carolinus)*, and greenbrier (*Smilax* sp.).

Other plants identified:

Bumelia lanuginosa
Callirhoë alcaeoides
Chloris verticillata
Cornus asperifolia
Croton monanthogynus
Festuca octoflora
Gleditsia triacanthos
Hordeum pusillum
Hypericum sp.
Monarda fistulosa
Opuntia humifusa
Opuntia tortispina
Tragia nepetaefolia
Vernonia altissima

In position and constiitution this association is intermediate between the oak—hickory and grama—beardgrass associations. The smooth sumac and persimmon, which are forest species, are the most conspicuous plants of the association. Most of the herbs, however, are species that occur in the grama—beardgrass association, and the sumac—grama association is more closely related to that than to the oak—hickory association.

Mammals of the sumac—grama association.	Records
Cryptotis parva	7
Mephitis mephitis mesomelas	1
Canis latrans subspecies	1
Citellus tridecemlineatus texensis	1
Geomys breviceps breviceps	4
Perognathus hispidus spilotus	32
Reithrodontomys montanus griseus	2
Peromyscus maniculatus ozarkiarum	32
Peromyscus leucopus noveboracensis	27
Sigmodon hispidus texianus	45
Neotoma floridana baileyi	1
Lepus californicus melanotis	1
Sylvilagus floridanus alacer	7

The plains pocket-mouse *(Perognathus hispidus)* is more abundant here than in the grama—beardgrass association. The deer-mouse *(Peromyscus maniculatus)* generally is more numerous here than in that association. The cotton-rat *(Sigmodon hispidus)* is locally abundant in this association. The harvest-mouse *(Reithrodontomys montanus)* is scarce in the area, and the little shrew *(Cryptotis parva)* occurs rarely here and lives beneath the limestone slabs. The wood-mouse *(Peromyscus leucopus)* wanders into the area from the oak—hickory and ravine forest associations, and some individuals probably live here. The woodrat *(Neotoma floridana)* sometimes lives where there are large blocks of limestone. The cottontail *(Sylvilagus floridanus)* is concentrated in the thickets and grassy cover. The jackrabbit *(Lepus californicus)* is less frequently encountered here than in the grama—beardgrass association. The pocket-gopher *(Geomys breviceps)* occurs where the soil is sufficiently deep for its burrows and is concentrated in the deeper soil of the prairie drains. The thirteen-lined spermophile *(Citellus tridecemlineatus)* is rare in the association, and the coyote *(Canis latrans)* ranges over the area. The striped skunk *(Mephitis mephitis)* occasionally inhabits dens beneath limestone slabs in the area.

Fig. 11. Bluejoint—switchgrass association, northeastern Oklahoma. Note height and density of the grassy cover.

Bluejoint—switchgrass association.—The sandstone and shale soils lying both east and west of the area of Oologah limestone and limited areas of deep soil in the limestone region support a heavy tall-grass sod. Much of this sod has been destroyed by cultivation and overgrazing, but occasional patches remain in pastures and along railroad tracks. The tall-grass prairie is on level or slightly rolling land, and there are few or no rocks at the surface in this area. The sod is formed principally by the bluejoint *(Andropogon furcatus)*,

prairie beardgrass *(Andropogon scoparius)*, and switchgrass *(Panicum virgatum)*. Another conspicuous grass is the three awn grass *(Aristida longespica)*. Other herbs typical of this association are the false indigo *(Baptisia bracteata)*, many flowered aster *(Aster multiflorus)*, croton *(Croton capitatus)*, blazing stars *(Liatris scariosa* and *L. acidota)*, and sage *(Salvia azurea* var. *grandiflora)*.

Mammals of the bluejoint—switchgrass association.	Records
Citellus tridecemlineatus texensis	Numerous
Geomys breviceps breviceps	2
Peromyscus maniculatus ozarkiarum	11
Microtus ochrogaster	1
Sigmodon hispidus texianus	Numerous
Sylvilagus floridanus alacer	Numerous

The deer-mouse *(Peromyscus maniculatus)* is the most abundant mammal of the bluejoint—switchgrass association. The prairie vole *(Microtus ochrogaster)* is a characteristic but rare species. The cotton-rat *(Sigmodon hispidus)* is abundant at times in this association. The cottontail *(Sylvilagus floridanus)* finds good cover in the tall grasses. The pocket-gopher *(Geomys breviceps)* and thirteen-lined spermophile *(Citellus tridecemlineatus)* also occur here.

Annotated List of Mammals

This list gives all known locality records of mammals in the Bird Creek region. Species that probably occurred in the region in recent time, but which are extinct there now, and species that may be in the region but which have not been taken there are also included in the list. All of the original information available about the ecology and life history of each species recorded from the region is included. Data bearing on the taxonomy of some of the species are presented, although no attempt is made here to revise the status of any of the forms. The taxonomic arrangement of the species follows Miller (1924), with the exception of subsequent changes in the nomenclature. The authors' names are used with the names of the forms that have been described since 1924.

Didelphis virginiana virginiana. Opossum. The opossum is reported to be common in the flood-plain forests of the Bird Creek region, where it probably ranges over all the minor associations in addition to the oak—elm association. An adult female was captured by H. S. Davis in the oak—elm association in Mohawk Park on September 3, 1935. A young, adult male was caught in daylight by A. P. Blair and P. F. Blair, Jr. in the same association near Catoosa on February 15, 1936, when the ground was covered with snow. An opossum was observed in a tree in the oak—hickory association in the Garnett area on a night in November, 1931. The species probably occurs also in the ravine forest association. The opossum is said to occupy old leaf nests of the gray and fox-squirrels, where individuals often are killed by hunters who shoot through the nests.

Scalopus aquaticus intermedius. Mole. Specimens of the mole from the Bird Creek region are somewhat darker than typical *intermedius* and represent a trend toward the darker *pulcher* and *machrinoides* of the Ozark region.

The mole occupies a type of habitat in the Bird Creek region that is quite different from that occupied by western members of the race. In western Oklahoma this animal is abundant in the stable sand dunes along the larger streams, but it is absent from the thin, baked soils of the adjacent uplands. In the Bird Creek region the mole is abundant in the heavy alluvium of the oak—elm association, where its preferred habitat is a moist forest floor with a good layer of humus and leaf-mold. This habitat is similar to that occupied by the races *pulcher* and *machrinoides* in the Ozark region. Seven moles were trapped in the oak—elm association in Mohawk Park during the summer of 1935. Four specimens were taken in this association in the Garnett area during the first week of June, 1936.

In the summer following the flood of 1935 the mole apparently was the only non-arboreal small mammal living in the flooded parts of the oak—elm association. At various times during the summer fresh mole burrows were seen several hundred yards from the nearest unflooded land. These animals apparently retreated to high land when the lowland was inundated and quickly reoccupied it after the water subsided.

Mole burrows occasionally have been found in upland situations where there is sufficient soil for their burrows. Numerous burrows were observed on the slopes of the Garnett ravines in the summers of 1935 and 1936, and occasional burrows were seen in cultivated fields adjoining the Garnett prairie. An adult, female mole was found at 7:30 p.m. on July 20, 1936, as it was traveling along a dusty road on the Garnett prairie. As there was cultivated land nearby it seems probable that the mole came from that rather than from the prairie, where burrowing would be almost impossible.

Cryptotis parva. Little shrew. A male and female of this species with 5 suckling young were collected by A. P. Blair and P. F. Blair, Jr., on June 4, 1936, 2 miles northeast of Garnett. The animals were captured in a nest of shredded grass located beneath a limestone slab in the sumac—grama association. The young were nearly grown, averaging 65 mm. in total length compared to 71 mm. in the adults. The shrews were kept in captivity for 24 hours during which time the young often were observed suckling the female. When the female was killed she was found to be pregnant. The 4 uterine swellings average 5.1 mm. in length.

The little shrew apparently is rare in the region, as no other records were obtained. It is essentially a grassland animal, but possibly it may occur also in the forest as it does at times in other parts of its range.

Blarina brevicauda carolinensis. Carolina shrew. The Carolina shrew was taken only in the oak—elm association. An adult male was trapped in this association in Mohawk Park on June 20, 1936, and an adult female was taken in Mohawk Park on July 30. An adult male was found dead by O. W. Letson on November 14, 1935, in Mohawk Park.

Three of these shrews were trapped in the oak—elm association on the Arkansas River flood-plain near Wekiwa, Tulsa County, west of the Bird Creek region. All were females, and all were taken on December 23, 1931.

Two of the animals were taken near large, rotting logs, and the third was caught in a trap set below the level of the ground in a hollow stump.

Pipistrellus subflavus subflavus. Pipistrelle. Four male pipistrelles were collected by A. P. Blair in a natural tunnel in the Garnett ravines. The tunnel was about 4 feet in diameter and penetrated about 30 feet into a limestone bluff. One of the bats was taken on February 22, 1935, and was in hibernation at the time. The others were captured on July 21, 1936.

Three bats that were seen flying together at dusk over the oak—elm association at Twin Lakes on August 3, 1935, were identified tentatively as pipistrelles on the basis of their small size and peculiar manner of flight.

The scarcity of this bat in the Bird Creek region probably is due to the scarcity of caves, as it is a cave dweller. Caves are abundant in the Ozark biotic district only 40 miles east of the Bird Creek region, and the pipistrelle is the most common bat of that district.

Eptesicus fuscus fuscus. Big brown bat. The big brown bat, like other species of bats, is rare in the Bird Creek region. The only record is of one captured by A. Clay in a building in Tulsa on August 4, 1935.

Lasiurus borealis borealis. Red bat. This tree bat probably occurs in all of the forest associations of the region, although it rarely is encountered in any of them. An adult female was shot at 8 p. m. on July 9, 1935, as it flew over Bird Creek in the Garnett area. A bat seen flying at dusk at the same station on August 1, 1935, was tentatively identified as a red bat. One was seen hanging on the underside of some leaves on a young oak in the lowland thicket association in Mohawk Park on August 23, 1936, and another was found in the same situation in the oak—elm association.

Procyon lotor hirtus Nelson and Goldman. Raccoon. No specimen is available, so the raccoon of the region tentatively has been referred to the race *hirtus,* which should occur in northeastern Oklahoma according to Nelson and Goldman (1930, 455).

The racoon is reported to be common along the streams of the Bird Creek system, where it lives in the larger trees of the oak—elm association. Racoon tracks frequently have been seen by O. W. Letson in Mohawk Park. In 1933 a family of raccoons that he estimated to be made up of an adult and 4 or 5 young frequented a trail in the park where he often observed their tracks. Raccoon tracks often were observed on the muddy banks of Bird Creek in Mohawk Park and near the mouth of Mingo Creek.

Mustela frenata primulina. Weasel. The weasel reported to occur in the Bird Creek region probably is this form, which is recorded from southeastern Kansas and central Oklahoma. The weasel apparently is rare in the region, and no specimens were obtained.

Mustela vison mink. Mink. The mink of northeastern Oklahoma tentatively has been assigned to the subspecies *mink* on the basis of a single skull

from 5 miles east of Broken Arrow, Wagoner County. The skull was from a young adult that was found dead and badly decomposed in the bed of Adams Creek on July 28, 1936.

Mink tracks were observed on numerous occasions on the mud banks of Bird and Mingo creeks. On December 17, 1932, the tracks of a mink were followed in the snow for about one-half mile near the mouth of Mingo Creek. A mink was seen by O. W. Letson in Mohawk Park in May, 1932, and another was seen in June 1933. A mink den was found by him in the park in January, 1933. This species probably is confined largely to the oak—elm, aquatic, and littoral associations in the region.

Spilogale interrupta. Prairie spotted skunk. A young adult female was captured beneath a house in Tulsa on August 18, 1935, by H. S. Davis. An adult male was captured in the oak—elm association in Mohawk Park on August 22, 1935. A spotted skunk was caught by O. W. Letson in a cat trap in the same association in Mohawk Park on January 28, 1938. Several of these skunks were seen dead on the highway in the grama—beardgrass association in the Garnett area. This apparently is a wide-ranging form like many other carnivores, and it probably occurs in most of the ecological associations of the region.

Mephitis mephitis mesomelas. Striped skunk. This skunk ranges widely in the region, and individuals have been observed in all of the major associations except the bluejoint—switchgrass. One was routed from its den beneath a limestone slab in the grama—beardgrass association on the Garnett prairie in October, 1931. It traveled about 400 yards to the nearest ravine and took refuge in a hole at the base of the rim-rock. Another was found beneath a limestone slab in the sumac—grama association. Skunk droppings often were seen in the ravine forest association in the Garnett area. Numerous skunks have been observed by O. W. Letson in the oak—elm association in Mohawk Park, and several skunk dens were found by him. A striped skunk was seen by him at 8:30 in the morning of February 12, 1938.

An adult male was found living almost in the center of Tulsa. It was discovered on August 31, 1935, in a length of pipe in a junk yard.

Canis lupus nubilus. Wolf. This wolf is reported to be still common in the Osage Savanna, but it probably is extinct in the Bird Creek region. A farmer claimed to have killed a wolf on the Garnett prairie in the spring of 1935, but it probably was a coyote. The name wolf generally is applied to the coyote in the region.

Canis latrans subspecies. Coyote. The coyote of the Bird Creek region probably is of the subspecies *latrans,* although no specimens are available.

Coyotes often were observed in the grama-beardgrass association. In the summer of 1936, a coyote regularly followed at dusk the top of a ridge in this association on the Garnett prairie. In a drizzling rain on a day in November, 1932, a coyote was encountered near the crest of a ridge in the sumac—grama association in the Garnett area. The animal was sighted about 40

yards away as I crossed a ridge, moving up-wind. On November 29, 1931, a coyote, pursued by hounds, was seen at Garnett mingling with a pack of mongrel dogs for a few moments before continuing its flight.

The coyote was not recorded from any of the forest associations, but this wide-ranging form probably crosses most of the associations of the region at some time.

Vulpes fulva. Red fox. There are no records of the red fox, but it possibly occurs in the region.

Urocyon cinereoargenteus subspecies. Gray fox. The gray fox probably occurs in the region, although it has not been recorded.

Lynx rufus subspecies. Bob-cat. The bob-cat still is found in the Osage Savanna (Okla. Game and Fish Comm. Report, 1936: 45), but it apparently is extinct in the Bird Creek region.

Citellus tridecemlineatus texensis. Thirteen-lined spermophile. The spermophile of the Bird Creek region has been referred to the subspecies *texensis* by A. H. Howell (unpublished revision).

This spermophile inhabits the grasslands of the region. The species is not common on the Garnett prairie, but one individual was seen there in the grama—beardgrass association on July 30, 1935, and a subadult female was taken there on July 4, 1936. One was seen there on July 5, 1936, in the sumac—grama association. Spermophiles often were seen in the bluejoint—switchgrass association in the vicinity of Tulsa.

The largest population of spermophiles was found on a golf course in Mohawk Park, where 15 specimens were collected on August 3, 1935, and many other individuals were seen. Two half-grown albino females were captured in the same place on August 14, 1935, and a third albino animal was seen. A female spermophile that was captured in Mohawk Park on August 17, 1935, gave birth to 8 young on the following day. One of the females of the litter was measured at the age of 24 hours. The total length was 58 mm.; the tail length 10 mm.; and the length of the right hind foot 6 mm.

Several toads *(Bufo woodhousii)* and one gopher-frog *(Rana areaolata)* were found in spermophile burrows in Mohawk Park on August 14, 1935. No spermophiles were found in the burrows from which these animals were taken.

Sciurus carolinensis carolinensis. Gray-squirrel. The gray-squirrel and fox-squirrel occur together in all of the forest associations of the region. There is no restriction of the gray-squirrel to lowland forests and the fox-squirrel to upland forests, as occurs in most of the range of the 2 species in the southeastern United States. There seems to be a slight predominance of gray-squirrels in the oak—elm association and a slightly greater abundance of fox-squirrels in the oak—hickory and ravine forest associations. The occurrence of the 2 species together in almost equal numbers in the Bird Creek region may be due to the restricted extent of the forest associations. In years of

abundance, population pressure probably forces individuals of both species out into all areas habitable by squirrels, so that no distinction is made between the upland and lowland forest.

An adult, male gray-squirrel was shot in the oak—elm association in the Garnett area on July 18, 1935. A subadult female was taken at the same station on July 27, 1935. An adult female was collected in the ravine forest association in the same region on July 27, 1935, and another was taken at the same station on September 5. Another adult female was taken in the oak—hickory association in the same area on July 12, 1935.

Gray-squirrels were very numerous in Mohawk Park in the summer of 1936, where they were observed in the oak—elm, pin oak swamp, and lowland thicket associations. In June, 1937, these animals were found to be extremely scarce in the region, and few were observed in Mohawk Park, where they had been abundant the previous year.

Sciurus niger rufiventer. Fox-squirrel. An adult, male fox-squirrel was collected in the ravine forest association in the Garnett area on July 27, 1935. Another adult male was taken in the oak—elm association at the same station on the same date. Fox squirrels also were observed in the oak—hickory association at this station. Fox-squirrels living in the ravine forest association were found to have the interesting habit, when pursued, of sometimes hiding beneath the limestone blocks littering the ravine slopes instead of taking refuge in the trees.

Fox-squirrels were about as abundant as gray-squirrels in Mohawk Park in the summer of 1936, where they were observed in the oak—elm, pin oak swamp, and lowland thicket associations. As many as 50 squirrels of the 2 species could be seen in an area of 2 or 3 acres in the early morning. This abundance may have been due in part to the fact that in the park squirrels are protected from hunting. In June, 1937, the fox-squirrels, like the gray-squirrels, were so scarce that hardly one could be seen where dozens existed the previous year. The fact that the increase of 1936 and the decrease of 1937 occurred in the 2 species simultaneously seems worthy of note. It would appear from this that whatever may be the factors governing the abundance of squirrels in the region they affect both species simultaneously.

Glaucomys volans saturatus. Flying-squirrel. An adult male and female were trapped in a large oak in the oak—elm association in Mohawk Park on August 20, 1935. A pregnant female was trapped in the same tree on September 5, 1935. The 4 uterine swellings averaged 30.5 mm. in length. A flying-squirrel was driven from a hole in a small tree in the oak—elm association in the Twin Lakes area by H. D. Chase in the spring of 1937. A few flying-squirrels have been seen by O. W. Letson in this association in Mohawk Park.

The flying-squirrel possibly occurs in the oak—hickory and ravine forest associations, although no records were obtained.

Geomys breviceps breviceps. Pocket-gopher. A young, adult female of this species was taken in the sumac—grama association in the Garnett area on

September 5, 1935, and an adult male and female were taken at this station the following day. An adult male was trapped in the same association in the Garnett area on June 8, 1936. An adult female was secured in the bluejoint—switchgrass association near Tulsa on August 17, 1935, and another was obtained on September 4.

Pocket-gopher mounds were abundant in the sumac—grama association on the Garnett prairie in 1933 and 1934. They were seldom seen in the summers of 1935 and 1936, which were periods of extreme drought. It seems probable that the droughts affected the pocket-gophers adversely by killing many plants thus reducing their food supply and by baking the soil so that it retarded the expansion of colonies. The pocket gophers in this region throw up mounds only when the soil is moist, so it seems probable that their burrows are enlarged only at such times. If young were produced during the drought years they probably would have difficulty in starting burrows if forced out of the maternal tunnels. No evidence of more than one individual living in a single system of burrows was found.

Eleven pocket-gophers were collected on a golf course in Mohawk Park in August and early September, 1935. They seemed much less reduced in numbers on the golf course, which was watered during the drought seasons, than in other parts of the Bird Creek region.

In the winter of 1937-38, O. W. Letson found pocket-gophers invading the oak—elm association in Mohawk Park. These animals are not known to have previously occurred in this association in the Bird Creek region. In the same winter, P. F. Blair, Jr. noted that pocket-gopher mounds were very abundant on the Garnett prairie in contrast to their scarcity there the preceeding 2 years. The rainy year, 1937, probably favored the increase of the pocket-gophers.

Perognathus hispidus spilotus. Plains pocket-mouse. This species is most abundant in the sumac—grama association. Three specimens were taken in this association on the Garnett prairie in November, 1933. Eight were taken at the same station in the summer of 1935. In the summer of 1936, one of these pocket-mice was taken in the sumac—grama association on the Twin Lakes prairie, and 20 of them were collected in the same association on the Garnett prairie.

Six specimens were taken in the grama—beardgrass association on the Garnett prairie in the summer of 1936. Two individuals were trapped in the plum thicket association on the Garnett prairie in September, 1936.

Numerous pocket-mouse burrows were discovered and excavated on the Garnett prairie (Blair, 1937, 188). All of the burrows were located at least partially beneath limestone slabs, and it is probable that the availability of these slabs is an important factor in the distribution of the pocket-mouse in the 3 associations in which it was found. This species was notably absent from ridges in the grama—beardgrass association on which there were no limestone fragments. Such ridges generally were found to be dominated by buffalo grass *(Buchloë dactyloides)*, and the lack of heavier cover may have been

responsible in part for the absence of the pocket-mice. In the sumac—grama association pocket-mice were most often taken in situations where the ground cover was dense but limited to pockets between the abundant limestone fragments. They were not taken in the prairie drains or other parts of the association where the grasses formed a continuous ground cover.

Reithrodontomys montanus griseus. Gray harvest-mouse. An adult male was trapped in the sumac—grama association on the Garnett prairie on June 9, 1936, and a subadult male was taken on July 22. An adult male was collected in the grama—beardgrass association on the Garnett prairie on July 3, 1936, and an immature male was taken the following day. An adult female was found on June 26, 1936, in a nest beneath a small limestone slab in the grama—beardgrass association on the Garnett prairie. There were no burrows beneath the slab, except a shallow depression containing a nest of cotton about one and one-half inches in diameter. The cotton probably was collected about an inhabited shack about 50 feet from the nest.

Peromyscus maniculatus ozarkiarum Black. Deer-mouse. A male deer-mouse was taken in the grama—beardgrass association on the Garnett prairie on December 30, 1931, and another was collected at the same station on April 2, 1932. Four individualas were captured there in the summer of 1935, and 15 were secured in the summer of 1936. Fifteen deer-mice were taken in the sumac—grama association in the Garnett area in the summer of 1935, and 17 were collected there during the summer of 1936. An adult male was taken in the plum thicket association there on September 2, 1936. In these associations deer-mouse burrows often were found beneath limestone slabs. The nests in these situations often were found to be made of the silky fruit of the oblong-leaved milkweed *(Asclepiodora viridis)*. Deer-mouse burrows also were found beneath clumps of prickly pear *(Opuntia tortispina* and *O. humifusa)*.

Eleven deer-mice were trapped in the bluejoint—switchgrass association near the southern edge of Mohawk Park in December, 1931. Most of the mice were trapped in an area that had been burned a short time before, and in this situation their burrows were easily located.

Peromyscus leucopus noveboracensis. Wood-mouse. A female wood-mouse was taken in the ravine forest association in the Garnett area on December 30, 1931. It was trapped near a hole at the base of a large limestone block on a ravine slope. Another was trapped at the same station on April 2, 1932. One wood-mouse was taken in the ravine forest association in the Garnett area on June 20, 1935, and 4 were collected in the same association in the Twin Lakes ravines on July 2, 1935. Thirteen were collected in this association in the Garnett area, and 16 were taken in the Twin Lakes area during the summer of 1936. The wood-mouse was found to occur in all parts of the ravine forest association. Along the rim-rock it was associated with the brush-mouse *(Peromyscus boylii attwateri)*.

Seven wood-mice were taken in the oak—hickory association in the Garnett area in the summer of 1935. Eleven wood-mice were taken at the same station

in the summer of 1936. The mice were most often captured near large, limestone blocks with burrows beneath them.

A male wood-mouse was captured beneath a log in the oak—elm association in the Twin Lakes area on March 4, 1932; a male and female were taken in this association at the mouth of Mingo Creek on March 19, 1932; and a male was collected in the same association near the mouth of Bird Creek on April 1, 1932. Fifteen wood-mice were taken in this association in Mohawk Park during the summer of 1935, and one was taken in it in the Garnett area. One of those taken in Mohawk Park was caught in a trap that was set about 20 feet from the ground in a large bur oak *(Quercus macrocarpa)* on August 31. Nine specimens were collected in this association in Mohawk Park during the summer of 1936. In the oak—elm association the wood-mouse was found to live beneath fallen logs, in brush piles, or in trees. Individuals were most often found living beneath or within the dryer and less decayed logs.

Six wood-mice were collected in the sumac—grama association on the Garnett prairie during the summer of 1935. Twenty-two specimens were obtained in the same association on the Garnett prairie in the summer of 1936. Many of the wood-mice taken in this association probably wandered into it from the oak—hickory and ravine forest associations. Some of them may have been living in the association, but no nests of these mice were found there.

Fifteen wood-mice were taken in the lowland thicket association in Mohawk Park in August, 1936. Four mice were captured in the sedge marsh association, and 2 males and one female were taken in the buttonbush swamp association in the same region and during the same month. An adult male was trapped in the pin oak swamp association in Mohawk Park on August 19, 1936, and another adult male was caught in the weed association in the same region on August 25. The scarcity of wood-mice in these associations probably was due to the lack of homesites. The animals taken here may have wandered into the areas from the oak—elm association.

Peromyscus boylii attwateri. Brush-mouse. Four brush-mice were taken at the base of the rim-rock in the ravine forest association in the Twin Lakes area, in the summer of 1935. Seventeen of these mice were trapped at the same station in the summer of 1936. These mice were trapped at the base of the rim-rock and on the steeper ravine slopes. None were taken where there were not large rock outcrops with an abundance of fissures and crevices, and none were taken on the more gentle ravine slopes. The niche occupied by this species and that occupied by the wood-mouse somewhat overlap. The wood-mouse generally was found to live on the more gentle slopes, but it occasionally was taken on the steep slopes with the brush mouse and at the base of the rim-rock. On the rim-rock the brush-mouse is associated with the woodrat *(Neotoma floridana)*. A pair of brush-mice was observed in a woodrat nest near Okesa, Osage County, on August 1, 1936.

It is surprising that the brush-mouse was not found in the Garnett ravines, as the conditions there apparently are suitable.

Sigmodon hispidus texianus. Cotton-rat. An adult, male cotton-rat was taken in the bluejoint—switchgrass association near the southern edge of Mohawk Park on January 17, 1932, where numerous runways were observed. On November 25, 1933, an adult female was trapped in the sumac—grama association on the Garnett prairie. On December 29, an adult male was found at the same station beneath a limestone slab. The nuts of the black hickory *(Carya buckleyi)* and pecan *(Carya pecan)* and acorns of the black-jack oak *(Quercus marilandica)* were stored beneath the slab. There were 2 well-marked trails leading to entrances to the burrows beneath the stone. The ground about the entrances was littered with weed and grass stems that had been cut into short lengths.

In the summer of 1934, cotton-rats were very abundant in the Bird Creek region. In July of that year these animals were found even on the barren ridges of the grama—beardgrass association in the Garnett area. In these situations, numerous rats and their nests and runways were observed beneath clumps of prickly pear *(Opuntia humifusa* and *O. tortispina)*. At that time the cotton-rat cycle was at a peak, and undoubtedly the pressure exerted by over-population in the habitats normally occupied by the species forced many individuals into less favorable situations.

Cotton-rats were so scarce in the summer of 1935 that only one individual was seen during 3 months in the field. This animal was found dead in the road 13 miles east of Tulsa in an area of sumac—grama association.

In the summer of 1936 cotton-rats again were abundant in the Bird Creek region, although they did not seem as numerous as in 1934 and were not found in the grama—beardgrass association. Forty-two specimens were taken in the sumac—grama association on the Garnett prairie during June and July.

Twelve adult and 28 immature cotton-rats were taken in the sedge marsh association in Mohawk Park from August 11 to 14. Many of the immature animals were so small that they seemed hardly large enough to get around, and others were of various larger sizes. The large proportion of these young cotton-rats of various sizes indicates that the species was breeding in early August in the sedge marsh association. No very young individuals were among the 16 cotton-rats trapped from August 11 to 14 in the weed association in Mohawk Park, and the 3 subadults taken were almost fully grown. Only one subadult was included in the 17 cotton-rats taken from September 2 to 5 in the plum thicket association on the Garnett prairie. It is evident from this that the species was not breeding in August in the weed and plum thicket associations. Throughout the summer there was an abundance of green food available in the sedge marsh association in the form of sedge plants. In the associations in which the cotton-rats were not breeding the grasses and other low plants were dead and dry during late summer. It may be possible that green food is necessary for the normal functioning of the reproductive processes of the cotton-rat.

Eight specimens were collected in the oak—elm association in Mohawk Park during June and July. One adult female was taken in the lowland thicket association in Mohawk Park on August 15, and 2 adult males were

caught in the buttonbush swamp association on August 8. One subadult female was caught on September 4, in the ravine forest association in the Garnett area.

The yearly fluctuations in numbers of cotton-rats from 1934 to 1936 correlate with the amount of spring rainfall. The spring of 1934 and that of 1936, preceding summers of cotton-rat abundance, were relatively dry, while that of 1935, preceding a summer of scarcity, was unusually wet. The wet spring possibly affected the cotton-rats adversely by flooding their homes and drowning any young that may have been produced.

On February 27, 1932, 2 adult females were collected and other cotton-rats were seen beneath cane "shocks" in a field about 2 miles south of Owasso. The house-mouse *(Mus musculus)* was abundant in the same habitat.

Neotoma floridana baileyi. Florida woodrat. One female and 3 adult, male woodrats were trapped in the ravine forest association in the Garnett ravines on April 16, 1932. Three specimens were taken at the same station in the summer of 1935, and 3 were collected there in the summer of 1936. A subadult male was collected in this association in the Twin Lakes ravines on June 30, 1936. In the ravine forest association woodrats were most often caught near the rim-rock. Their bulky nests of sticks and leaves could be seen in many places in the larger crevices in the rim-rock. The woodrats also were trapped on the ravine slopes near the larger limestone blocks. They occupied burrows beneath the blocks.

Five wood-rats were taken in the oak—hickory association in the Garnett area during the summer of 1935. One of these was trapped near the entrance to a burrow under a large limestone slab. All of the woodrats were taken in situations in which there were more and larger limestone fragments than in most of the area.

An adult, male woodrat was caught in the sumac—grama association on the Garnett prairie on November 12, 1932. It was trapped in the entrance to burrows beneath a large limestone slab, which was about 300 yards from the nearest part of the ravine forest association. Several fruits of the persimmon *(Diospyros virginiana)* were found in and about the burrows.

A woodrat was driven from a hole in a dead snag in the oak—elm association about 3 miles west of Catoosa on December 10, 1932. An adult female was shot in a brush pile in the same association near Catoosa by P. F. Blair, Jr. on February 15, 1936. In the summer of 1935, there were abundant signs of a woodrat living in a dead spotted oak *(Quercus shumardii)* standing in the oak—elm association in the Garnett area.

Microtus ochrogaster. Prairie vole. The only specimen of the prairie vole known from northeastern Oklahoma is an adult female that was taken a small area of bluejoint—switchgrass association about one mile east of Garnett on April 2, 1932. The Bird Creek region must be very near the southern limit of the range of this species. Dice (1922, 46) found that temperatures in excess of 98° F. were fatal to individuals of this species collected near

Urbana, Illinois. If animals of this species show a similar response in the Bird Creek region, such summers as that of 1936, when the average temperature of the month of August was 91° F., must have considerable effect in limiting the range of the species. Dice *(loc. cit.)* concluded that the westward distribution of the species is limited by the drying up of the grassland at some time of the year. This would mean that in the Bird Creek region the species would be limited to the bluejoint—switchgrass association, and that west of this region it would occur only in post-climax areas of tall grass. The destruction of much of the bluejoint—switchgrass association in northeastern Oklahoma through cultivation and overgrazing has greatly reduced the extent of habitats suitable to this species.

Pitymys nemoralis. Pine vole. Pine voles were found in the Bird Creek region only in the oak—elm association. In the spring of 1929 or 1930, the number of pine voles increased almost to epidemic proportions. At that time almost every log or bit of fallen wood on the Verdigris River flood-plain opposite the mouth of Bird Creek sheltered one or more of the animals. An adult male was taken in the Twin Lakes area on February 13, 1932, and 2 adult females were taken in the same area on March 4, 1932. Two adult females were taken near the mouth of Mingo Creek on March 18 and 19, 1932. Another was collected near the mouth of Bird Creek on April 1, 1932. A female with 5 very small young was captured beneath a rotting log in the Twin Lakes area on February 15, 1933. The nest was made of grass, leaves, and shredded elm bark. When the female was disturbed she ran from the nest with the young clinging to her teats. This behavior was observed on many occasions when females with young were disturbed. A half-grown male was captured in a nest of grass and leaves beneath a rotting log in the Garnett area on November 18, 1933. The nuts of the bitternut hickory *(Carya cordiformis)* and pecan *(Carya pecan)* and the acorns of the spotted oak *(Quercus shumardii)* were found stored in a chamber beneath the log. The pine vole was found to occupy a niche slightly different from that occupied by the wood-mouse *(Peromyscus leucopus noveboracensis)*. The wood-mice were found under the more dry and less decomposed logs. Pine voles were found under rotten, crumbling logs with a high water content. In wet seasons pine voles were found at the Twin Lakes in nests beneath logs only a few feet from temporary ponds. There often was water less than a foot below the surface of the ground beneath the logs. In such situations the "wells" of crayfish often were found beneath the logs which covered the pine vole nests. Pine voles sometimes were found in winter living beneath corn "shocks" in flood-plain fields surrounded by the oak—elm association.

The population of pine voles in the Bird Creek region was almost wiped out by the wet spring of 1935, when flood waters stood on the flood-plains of the region for several weeks. None of these animals were found during the summers of 1935 and 1936, except in Mohawk Park, where the flood-plains were protected by a dike. An adult male and female were captured beneath a log in Mohawk Park, by A. P. Blair and P. F. Blair, Jr. on March 9, 1936. Five specimens were collected in Mohawk Park during the summer of 1936.

Ondatra zibethica cinnamomina. Muskrat. A young male was collected in a small pond about 2 miles north of Dawson on November 14, 1932. An adult male was taken in a fish hatchery pond in Mohawk Park on August 28, 1935, and 3 adult males were collected at the same place in August, 1936. These animals are a persistent nuisance in the hatchery ponds, as they honeycomb the walls with their burrows. Muskrats are reported to be fairly common in Mohawk Park. They are said to have been common along Bird Creek and its tributaries a few years ago, but they are scarce or lacking there now.

Mus musculus musculus. House mouse. An adult female was trapped in the sumac—grama association on the Garnett prairie on July 15, 1935. An adult male was taken in the lowland thicket association in Mohawk Park on August 17, 1936. Many house mice were found with cotton-rats *(Sigmodon hispidus texianus)* under cane "shocks" in a field about 2 miles south of Owasso on February 27, 1932.

Zapus hudsonius campestris. Jumping-mouse. An adult, female jumping-mouse was taken in the lowland thicket association in Mohawk Park on August 17, 1936. Four days later an adult male was taken in the same association 170 yards from where the female was caught. The specimens extend the known range of the species southward from central Kansas into northeastern Oklahoma. The specimens are somewhat smaller and paler than typical *campestris,* but the differences are not sufficient to warrant subspecific recognition on the basis of no more material than now is available.

Lepus californicus melanotis. Jackrabbit. Jackrabbits were observed many time in the grama—beardgrass association on the Garnett prairie. One was shot there on November 24, 1932, and another was killed on November 26. Four were shot at the same station on October 1, 1933. A female that was shot on July 22, 1935, in this association on the Garnett prairie contained one large embryo. A jackrabbit that was pursued by dogs at the same station on June 21, 1935, killed itself by running into the bottom strand of a barbed-wire fence and cutting its throat.

Jackrabbits were seen also in the sumac—grama association in the Garnett area, but they were much less frequently encountered there than in the grama—beardgrass association. They were not seen in the bluejoint—switchgrass association except where hay meadows had been mowed.

An adult male and suckling female were shot on June 27, 1935, about one mile northeast of Garnett. The 2 animals were moving about together, and they hopped from an oat field across a road into a corn field. The stomach of each was filled with masticated oat grains.

Sylvilagus floridanus alacer. Cottontail. Following a heavy snow, 6 cottontails were found beneath tree roots and in other protected spots in the oak—elm association near the mouth of Mingo Creek on December 27, 1932. An adult male was shot by P. F. Blair, Jr. in the same association about 2 miles northwest of Catoosa on January 11, 1936. On numerous occasions cottontails were observed in this association in Mohawk Park and in the Garnett area.

Seven cottontails were shot in the ravine forest association in the Garnett area on a day in the fall of 1933. Cottontails were observed in the Garnett ravines on numerous other occasions. They often would escape into retreats beneath the limestone blocks on the ravine slopes or into crevices in the rimrock. These animals often were observed in the oak—hickory association in the Garnett area, where 5 specimens were taken in September, 1936. The cottontails were most frequently encountered in the parts of the association in which there was heavy cover.

Cottontails frequently were observed in the sumac—grama association in the Garnett area. A young male was shot there on June 27, 1935, and an adult male was collected there by P. F. Blair, Jr. on November 20, 1935. Five cottontails were obtained in the same place during the first week of September, 1936. They were found to be rare in the grama—beardgrass association, but 3 specimens were taken in that association in the Garnett area on October 1, 1933. The cover is rather sparse for cottontails in this association. They never were seen on the more barren ridges dominated by buffalo grass *(Buchloë dactyloides)*. Cottontails frequently were seen in the plum thicket association on the Garnett prairie. They also were often seen in the bluejoint—switchgrass association in various parts of the Bird Creek region.

A cottontail was seen in the sedge marsh association in Mohawk Park on August 11, 1936. Swamp-rabbits *(Sylvilagus aquaticus)* were observed in the same situation. Cottontails were observed on numerous occasions in the buttonbush swamp association in Mohawk Park and in the Twin Lakes area. In the summer of 1936, they frequently were encountered in the weed and lowland thicket associations in Mohawk Park.

Sylvilagus aquaticus aquaticus. Swamp-rabbit. Four swamp-rabbits were shot in the oak—elm association about 2 miles northwest of Catoosa on December 10, 1932. There was a 2 inch cover of snow on the ground, and one swamp-rabbit was seen and tracked in the snow. For the first 40 yards after being flushed the rabbit averaged 6 feet at a jump. Then the jumps lengthened to about 12 feet. When the animal crossed a weedy area the jumps shortened to 6 or 8 feet, but as soon as the rabbit left this and entered an area of bare snow the jumps lengthened to 10 and 12 feet. The tracks finally were lost among other rabbit tracks in an extensive thicket. On February 9, 1935, A. P. Blair and P. F. Blair, Jr. frightened a swamp-rabbit from a brush pile at the same station and shot it. An adult female was found dead in the oak—elm association in Mohawk Park on June 22, 1936. An autopsy showed no observable cause of death.

A swamp-rabbit was shot in the buttonbush swamp association about 2 miles northwest of Catoosa on November 20, 1932, and another was obtained there on November 25, 1932. Three specimens were collected in the same situation by A. P. Blair and P. F. Blair, Jr. in February, 1936.

These animals often were observed in the sedge marsh association in Mohawk Park and on the Bird Creek flood-plain near Catoosa. On August 11, 1936, both swamp-rabbits and cottontails were seen in this association in

Mohawk Park. Swamp-rabbits range through the aquatic and littoral associations, and when pursued they show no hesitation about crossing ponds to escape. A swamp-rabbit was seen in the middle of a small pond in Mohawk Park by H. D. Chase and A. P. Blair on a night in the spring of 1935. Swamp-rabbits also were observed in the lowland thicket association in Mohawk Park. They often were found in the fall and winter in bottom-land corn fields.

Odocoileus virginianus subspecies. White-tailed deer. This species undoubtedly occurred formerly in the forest associations of the Bird Creek region.

Bison bison bison. Plains bison. Bones of this species occasionally are found in terrace deposits in the region.

Dasypus novemcinctus texanus. Nine-banded armadillo. The armadiilo is known from only one individual that may have had human assistance in reaching the region (Blair, 1936, 293).

Effects of Drought

The summers of 1934, 1935, and 1936 were abnormally dry in the Bird Creek region, as in many parts of the central United States. The average rainfall in this region during the months of June, July, and August is 11.42 inches (average of 43 year record at Tulsa and 15 year record at Claremore). There was a total of only 5.54 inches (average of Tulsa and Claremore station records) of rainfall during these months in 1934. In these months in 1935 there was a rainfall of 11.82 inches, but approximately 10 inches of this came in the first 20 days of June. In 1936 only 2.87 inches of rain fell during June, July, and August. During the first 8 months of that year the

Fig. 12. Oak—elm association in Twin Lakes area, Bird Creek region, northeastern Oklahoma, June 27, 1937. A section severely damaged by the drought of 1936. Note dead trees in center foreground.

rainfall totaled only 9.55 inches, compared to an average of 27.23 inches for that period in previous years.

The dry summers of 1934 and 1935 had only moderately severe effects on the vegetation of the region. The most conspicuous results of these dry summers were the absence or scarcity of many late summer and autumn annuals and the failure of fall-fruiting grasses to set seed. The flood-plains of the region were extremely barren in the summer of 1935, as their inundation for several weeks in the spring killed much of the under-cover. The cumulative effects of the droughts of 1934 and 1935 may have intensified the effects of the drought of 1936 through the reduction of moisture in the soil.

The great drought of 1936 had a conspicuous effect on the oak—elm association in some parts of the Bird Creek region. Numerous trees of several species were killed, and the forest floor was opened up to many invading annuals. One of the most severely damaged sections in the Twin Lakes area was examined on June 28, 1937. A census was made of the trees in a strip 165 feet wide along the north shore of the south lake, comprising 1.4 acres (Table 1).

TABLE 1

Census of trees in area of 1.4 acres in Twin Lakes area, showing number of live trees and the number killed or severely injured by the great drought of 1936.

Diameter Breast High	Live			Top-killed			Killed		
Species	0-5″	6-15″	16-∞	0-5″	6-15″	16-∞	0-5″	6-15″	16-∞
Ulmus americana	5	22	5				6	19	4
Celtis laevigata	18	29	1		2	1	6	18	1
Carya illinoensis	8	25	4			2	2	1	2
Fraxinus p. lanceolata	7	18	2				1	1	
Quercus palustris	3	8	2			1			1
Diospyros virginiana	2	15						1	
Morus rubra	3	2		1	1				
Crataegus sp.	8								
Platanus occidentalis			1			3			1
Cercis canadensis							1		
Acer negundo								2	
Quercus muhlenbergii		2							
Quercus sp.							1		
Viburnum rufidulum							1		
Gymnocladus dioica	1								
Bumelia lanuginosa	3								
Celtis occidentalis	1							1	
Quercus shumardii									1
Prunus mexicana									3
Prunus sp.	1								
Gleditsia triacanthos	1	1							

The American elm *(Ulmus americana)* and hackberry *(Celtis laevigata)*, which were the principal dominants of the area, suffered most from the drought. The American elm was most severely affected, losing 29 of 61 trees on the plot, or 47 per cent of the elm trees. The hackberry was somewhat less severely damaged. Twenty-five of the 76 trees of this species were killed, and 3 suffered some top killing. The trees completely killed comprise 34 per cent of the individuals of this species in the plot. In all, 15 of the 21 species of trees in the plot suffered some damage from the drought, either through top-killing or through complete loss of life. Thirty per cent of all of the trees in the plot were killed.

The loss of so many of the trees allowed sunshine to penetrate to the forest floor. This resulted in the replacement of most of the shade tolerant herbs by annual weeds, of which the most conspicuous was the high-water weed *(Iva xanthifolia)*. Among the undershrubs in the plot, many of the roughleaf dogwood *(Cornus asperifolia)*, swamp holly *(Ilex decidua)*, prickly-ash *(Zanthoxylum americanum)*, and prairie rose *(Rosa setigera)* were killed to the ground. On the other hand, the coral berry *(Symphoricarpos orbiculatus)*, hawthorn (*Crataegus* sp.), and blackhaw *(Viburnum rufidulum)* apparently did not suffer.

The above described plot is an extreme example of the effects of the drought on the oak—elm association in the Bird Creek region. Most of the trees killed were within 80 feet of the lake shore, and they probably had shorter roots than those farther from the lake. Trees also were killed in other parts of the association, but not in such great numbers.

The oak—hickory association did not suffer as severely as did normally moist situations in the oak—elm association, like that described above. However, trees were killed in many places in the oak—hickory association, and numerous other trees that were not killed suffered top-killing or the loss of large limbs. There also was in this association a heavy loss in the shrub layer, where the smooth and dwarf sumacs *(Rhus glabra* and *R. copallina)* were stripped of their leaves and bark by grasshoppers. The grasshoppers destroyed these plants apparently because other food was scarce, due to the drought. The drought resulted in a general opening up of the forest in some parts of this association and in restricting the extent of the association where it was encroaching on adjoining grasslands.

The effects of the drought on the grassland associations of the region were less conspicuous and apparently less severe than on the forest associations. The tall grasses achieved very little growth during 1936, and most of them failed to set seed. There may have been some decrease of tall grasses and increase in short grasses in the grama—beardgrass association similar to that found by Weaver and Albertson (1936, 567) in Kansas and Nebraska, but no detailed study of the composition of the grassland vegetation was made. There were no changes sufficiently great to alter the general aspect of any of the grassland associations, and following the wet spring of 1937, these associations looked very much like they did before the drought years.

The most conspicuous effects of the great drought of 1936 in the Bird Creek region were the death of many trees of the dominant species in the oak—elm association, particularly in normally moist situations, and the death of numerous trees in the oak—hickory association, thereby reducing the density and extent of that association.

Undoubtedly the changes in the vegetation caused by the drought resulted in changes in the local distribution and abundance of some of the mammals in the region, but information about any such changes that may have taken place is not available.

Population Studies

In order to obtain a measure of the abundance of small mammals in the various associations of the region, most of the traps employed during the summer of 1936 were set in measured quadrats or in single lines of measured length.

A quadrat 4 by 5 chains in dimensions was found to be a convenient unit and was employed in most situations where the extent of the association was sufficient to permit its use. Where an association was too small to allow the use of a quadrat of this size smaller quadrats were employed. The large quadrats contained 5 parallel lines of traps, the trap lines being one chain apart and 5 chains long. Each trap line consisted of 20 traps spaced about 16 feet apart. The close spacing of the traps made sure that most of the mammals would be trapped out of the area in a short period of time. In the smaller quadrats the trap lines generally were also placed one chain apart, and the spacing of the traps was the same as in the large quadrats. The lines were laid out with a steel tape, and a compass was used in heavy cover. Small cloth banners, placed on stakes at intervals of one chain along the lines, facilitated the laying out of the quadrats.

The single trap lines generally were 25 chains in length. A line of this length contained 100 traps spaced about 16 feet apart. A trap line about 12 chains long containing 50 traps, and another about 6 chains long containing 25 traps also were employed at various times. The measured trap lines are more easily set than the quadrats and can be placed in parts of ecological associations which are of such shapes that quadrats can not easily be laid out.

Small, metal, live traps of several types were used except in 2 of the quadrats where snap traps were employed. The snap traps were of the "Museum Special" type. All of the traps were numbered serially. Both the live and snap traps apparently functioned equally well. The number of the trap in which each animal was taken was recorded together with the sex and approximate age class (adult or immature) of the animal. All of the mammals caught were removed from the area.

Each quadrat or single trap line ordinarily was maintained for 4 nights of trapping, although in a few cases the period of trapping was longer. In order that the calculations of relative abundance in the various associations may be comparable only the catch of the first 4 nights will be considered.

The animals taken in an area during the first 4 nights of trapping, however, do not necessarily comprise the actual population of the area over which the traps have been set. It is probable that not all of the animals whose home ranges are crossed by the trap lines are captured in this period of time, although W. H. Burt (unpublished manuscript) has found that, in areas in southern Michigan in which he knew the population of wood mice, 90 to 95 per cent of the population could be taken in 4 nights of trapping. Some of the individuals taken on a quadrat have home ranges that extend beyond the limits of the outer traps, and therefore the area trapped out is larger than the area on which the traps are set. Another complicating factor is the possibility that some animals will wander into the area from unknown distances after the resident animals have been trapped.

This method of trapping does, however, give an index of relative abundance that is free of the most serious of Dice's (1931, 377) criticisms of the "trap-night" method of Grinnell (1914, 92). The use of standard time, areal, and trapping units makes quadrats set at approximately the same time of the year comparable. The even spacing of the traps reduces the probability of error due to the personal factor involving skill and experience in setting traps. The method is more reliable than that of Townsend (1935, 15) in which the areal units were so small (17/80 acre) that in wandering from adjacent areas, for which no allowance was made, obviously contributed more to the size of the catch than the population within the measured area.

The trapping records detailed below give, for the summer of 1936, a measure of the relative abundance of a few of the species of the region in the several associations in which they were found. Several other species of mammals were taken in the quadrats and trap lines, but so few individuals were obtained that little more can be said of these species than that they were rare in the Bird Creek region in the summer of 1936.

Peromyscus maniculatus ozarkiarum. Deer-mice were taken in 2 quadrats in the grama—beardgrass association and in 4 quadrats in the sumac—grama association. The number of mice taken per quadrat in one of these associations is comparable with the catch per quadrat in the other. This is true because the quadrats were of the same size (4 by 5 chains each); they were set at approximately the same time of the year (June-July); and each quadrat was located in the midst of a large, uniform area, making the chances of inwandering the same in each quadrat. Ten deer-mice were taken from June 24 to 27 in one quadrat in the grama—beardgrass association, and 5 were caught in the other from July 3 to 6. The 4 quadrats run in the sumac—grama association in June and July took 6, 4, 3, and 3 deer-mice respectively. This suggests that deer-mice were more abundant in the grama—beardgrass than in the sumac—grama association in the summer of 1936.

Perognathus hispidus maximus. Pocket-mice were taken in all of the quadrats in which the deer-mice were caught, and the catch of pocket-mice in the 2 associations can also be directly compared. Three pocket-mice were captured in one of the 2 quadrats in the grama—beardgrass association, and one indiivdual was taken in the other. The 4 quadrats in the sumac—grama

association took 7, 6, 5, and 2 pocket-mice respectively. This seems to indicate that these mice were more abundant in the sumac—grama than in the grama—beardgrass association.

Peromyscus leucopus noveboracensis. The numbers of wood-mice taken per quadrat in the various associations are not comparable, because quadrats and single lines of various sizes were necessitated by the variations in the size and shape of the areas covered by many of the associations. However, the abundance of wood-mice in the various associations may be compared if the average catch of these animals per acre in each can be calculated. The reliability of these calculations depends on the accuracy with which the area trapped out can be computed. The home ranges of some of the mice taken will lie partially outside of the measured area, and an allowance for this must be made in the calculation of the area trapped out. W. H. Burt (unpublished manuscript) has found that the average width of the home range of the wood-mouse in southern Michigan is about 250 feet. If we assume that the home range of the wood-mouse is the same in the Bird Creek region as in southern Michigan, 125 feet (one-half of the average width of a home range) may be added to each side of each quadrat or single line, except on the sides bounded by unfavorable habitats.

The chief difficulty in determining the average catch per acre lies in the impossibility of distinguishing between animals whose home ranges are at least partially within the measured area and those that wander in after the residents have been removed. The computed numbers per acre are not strictly comparable because of this inability to distinguish between resident and invading individuals and because there are less chances of invasion in partially or completely isolated quadrats than in quadrats set in the midst of extensive associations. However, the error from this source is believed not to be great enough to obscure the larger differences in numbers of wood-mice in the various associations, and the computed number per acre probably is a rough approximation of the population per acre.

The greatest concentration of wood-mice was in the ravine forest association, where the computed catch per acre was 2.01 animals (Table 2). The

TABLE 2

Computed catch of wood-mice *(Peromyscus leucopus)* in the Bird Creek region. One hundred and twenty-five feet beyond the traps added to each side of the quadrats and lines, except on sides bounded by unfavorable habitats.

Associations	Total Number Caught	Computed Acres	Computed Number Per Acre
Oak—hickory	12	7.57	1.58
Ravine forest	29	14.39	2.01
Oak—elm	9	25.41	.35
Lowland thicket	12	21.04	.57
Pin oak swamp	1	9.02	.11

computed catch of wood-mice in the oak—hickory association was 1.58 individuals per acre, indicating that these animals probably were somewhat less abundant there than in the ravine forest association. The computed catch per

acre was so small in the oak—elm, lowland thicket, and pin oak swamp associations that it signifies little more than that wood mice were scarce in those associations during the summer of 1936.

Wood-mice occasionally were found in the sumac—grama association on the Garnett prairie, as stated in the annotated list. In the summer of 1936, one individual was taken in a quadrat in this association on June 26, and 2 others were taken on July 21 and 23, respectively. These animals probably were wanderers from the adjoining oak—hickory and ravine forest associations. A quadrat in the sumac—grama association had one of its long sides parallel to the edge of the oak—hickory association which was about 100 yards away. Nineteen wood-mice were taken in this quadrat from June 6 to 10. All of the mice appeared to be young of the year, although some had attained adult pelage. Young wood-mice were found by Burt (unpublished manuscript) to wander more than old animals and to push out from their preferred habitats into unfavorable situations during their search for home-sites. The wood-mice taken in this quadrat probably were wanderers from the nearby oak—hickory association. Wood-mice were taken rarely later in the summer in the quadrats in the sumac—grama association, probably because young mice were not being produced then.

Sigmodon hispidus texianus. The problem of comparing the numbers of cotton-rats taken in the various associations is more difficult than that of comparing the numbers of wood-mice. The average size of the home range of the cotton-rat is not known, so in the computation of the average catch per acre an arbitrary addition of one chain has been made beyond the outermost traps on each side of the quadrat on which there was a habitat occupied by cotton-rats. The allowance of one chain is based on a general knowledge of the habits of the species, which indicates a smaller home range than that of the wood-mouse.

The computed number of cotton-rats per acre is much greater for the sedge marsh association (88.89 individuals) than for the other associations in which they were taken (Table 3). All of the cotton-rats taken in this

TABLE 3

Comparative catch of cotton-rats *(Sigmodon hispidus)* in the Bird Creek region. One chain added to each side of the measured areas, except on sides bounded by unfavorable habitats.

Associations	No. of Quadrats of Lines	Total No. Animals	Adults Per Acre	Immature Per Acre	Total Per Acre
Sedge marsh—August 11-14	1	40	26.67	62.22	88.89
Weed—August 22-25	1	16	3.32	.77	4.09
Plum thicket—Sept. 2-5	1	17	6.78	.42	7.20
Sumac—grama—June-July	4	40	.55	.91	1.46
Oak—elm—June-July	4	8	.31	.10	.41
Lowland thicket—August	3	1	.09	0.00	.09
Buttonbush—August 7-10	1	2	.58	0.00	.58

association apparently were residents, as the area trapped was isolated. It was surrounded by the pin oak swamp association, in which cotton-rats were not taken. The computed catch per acre is greater in the plum thicket association (7.20 animals), weed association (4.09), and sumac—grama association (1.46) than in the oak—elm, lowland thicket, and buttonbush swamp associations. In these latter associations so few cotton-rats were taken that it can only be said that the species was scarce in these habitats. The relative abundance or scarcity of cotton-rats in the various associations is correlated in a general way with the amount of ground cover available. The heaviest ground cover was present in the sedge marsh association, where the computed catch per acre was greatest. Less cover was available in the weed, plum thicket, and sumac—grama associations, where the computed catch per acre was much less than in the sedge marsh association. Very little ground cover was present in the oak—elm and lowland thicket associations because of the shading of the forest floor by the shrub layer, and cotton-rats were scarce in these associations. They also were scarce in the buttonbush swamp association, where there was little ground cover, because the buttonbushes shaded the ground. It is not known whether the ground cover is more important as protection to the cotton-rats or as a source of food, but it probably is important as both.

The population studies presented above, while obviously subject to a considerable degree of error, give a more reliable measure of mammalian abundance than any other method in use at present, except the marking and retrapping of live animals on measured plots, a technique that is not practicable in reconnaissance work. The data obtained through the above studies give a usable measure of the abundance of a species in the various ecological associations in which it occurs.

General Ecological Relationships of the Region

The Bird Creek region is intermediate in position between the eastern deciduous forest and the grasslands of the Great Plains, and it is part of an area about 100 miles wide which is neither predominantly forest nor grassland. This strip in northern Oklahoma liest west of the Ozark biotic district (Fig. 2) which is a part of the eastern deciduous forest. West of this strip lies the Mixed-grass Plains district of the Great Plains grasslands. The Bird Creek region is located approximately midway between the western border of the Ozark district and the eastern border of the Mixed-grass Plains district.

Ecological associations of both the eastern deciduous forest and the Great Plains grasslands occur in the Bird Creek region. The oak—elm, ravine forest, and oak—hickory associations are related to certain eastern deciduous forest associations, as represented in the Ozark district (Blair and Hubbell, 1938). The Great Plains grasslands are represented in the Bird Creek region by the grama—beardgrass and plum thicket associations, which resemble typical associations of the Mixed-grass Plains district. The bluejoint—switchgrass association is closely related to the typical association of the tall-grass prairies, as represented in Illinois and Indiana (Clements, 1920, 131). The sumac—grama association of the Bird Creek region is intermediate between the oak—hickory

association of the eastern deciduous forest and the grama—beardgrass association of the Great Plains grasslands.

The degree of relationship of the several associations of the Bird Creek region to their nearest related associations of the nearby major biotic areas varies considerably. The oak—elm and ravine forest are very similar respectively to associations of the same type in the Ozark district, and differ chiefly from them in the absence of certain mesophytes. The important dominants are the same, and in general aspect the oak—elm and ravine forest associations of the Bird Creek region are quite similar to the related associations of the Ozark district.

The oak—hickory association differs chiefly from the related association of the Ozark district in the presence of some herbs having affinities with the Great Plains grasslands. In general aspect, however, the oak—hickory association of the Bird Creek region is fairly similar to the related association in the Ozark district.

The grama—beardgrass association is characterized by the admixture of tall and short grasses, just as in the Mixed-grass Plains district. It differs from the similar association of the Mixed-grass Plains in being restricted to thin limestone soil, where residual limestone fragments are an important feature of the environment. The bluejoint—switchgrass association is characterized by the same tall grasses and by many of the other herbs that are present in the related association in the tall-grass prairies.

The sumac—grama association is related to both the oak—hickory and grama—beardgrass associations and has no close counterpart in the nearby biotic areas. The presence of the smooth sumac and other woody plants shows its relationship to the oak—hickory association, and the abundance of herbs that occur in the grama—beardgrass association shows its relationship to that association.

Each of the ecological associations, with one exception, is more or less closely related to an association that occurs in one of the 3 nearby biotic areas, and shows little relationship to the associations of the others. The only exception is the sumac—grama association, which has no close counterpart in any one of the 3 biotic areas.

In amount of moisture available for plant growth, the Bird Creek region is intermediate between the eastern deciduous forest region and the Great Plains. The average annual temperature is approximately the same at the same latitude in the Bird Creek region and in the nearby eastern deciduous forest and Great Plains grasslands. However, the western part of the eastern deciduous forest, as represented at Fort Smith, Arkansas, has an average annual rainfall of 38.85 inches, and an average wind velocity of only 7.9 miles per hour, while the Great Plains grasslands, as represented at Oklahoma City, have an average annual rainfall of only 31.59 inches, and an average wind velocity of 11.4 miles per hour. The Bird Creek region, as represented at Broken Arrow, the nearest weather station with wind velocity data, has an average annual rainfall of 38.93 inches and an average wind velocity of 11.7

miles per hour. There is therefore approximately the same amount of rainfall as in the forest at Fort Smith. However, the rate of evaporation in the Bird Creek region is greater because of the greater wind velocity. The wind velocity is approximately the same at Broken Arrow, representing the Bird Creek region, and at Oklahoma City, in the grasslands, but the amount of rainfall is greater in the Bird Creek region.

Other factors than wind velocity probably aid in making the amount of moisture available for plant growth in the Bird Creek region less than the annual rainfall of the region would seem to indicate. The rainfall often is of the "cloudburst" type, and often a large part of the summer rainfall will be concentrated in a few days or weeks, as in 1935. With such concentrated rainfall the runoff is very rapid, so little moisture soaks into the soil, where it can be utilized by plants.

In this transition region edaphic factors determine to a large extent whether at any given place forest or grassland associations will occur. The alluvial soil on the flood-plains of the streams generally is deeper and more moist than soils on the upland and is mostly occupied by the oak—elm association. The several minor associations that occur also on the flood-plain are seral communities in the development of the oak—elm forest from aquatic associations, or they are seral communities that have resulted from the cutting of the original forest. Ravine slopes, from which evaporation is less rapid than from more level situations, support the mesic ravine forest association. Relatively level, upland areas of limestone soil adjoining the ravines are occupied by the oak—hickory association. This association, which is encroaching on the grasslands, is considered the climax association of the region (Bruner 1931, 193). Limestone soil that is thinner than that occupied by the oak—hickory association becomes very dry in summer and is occupied by the grama—beardgrass association, which is related to the semi-arid grasslands of the Great Plains. Shale soil in the Bird Creek region is occupied by the bluejoint—switchgrass association.

Since the oak—hickory association constitutes the climax in the Bird Creek region the oak—elm and ravine forest associations represent post-climaxes (defined by Weaver and Clements, 1929, 78), and the bluejoint—switchgrass and grama—beardgrass are sub-climax associations.

As a result of the edaphic control of the occurrence of the various ecological associations in the Bird Creek region, there is here an interdigitation of the associations representing the eastern deciduous forest with those of the tall-grass prairies and with those of the Great Plains grasslands. These associations maintain their individual characteristics in the Bird Creek region, therefore ecological associations of the eastern deciduous forest, of the Great Plains grasslands, and of the tall-grass prairies here exist side by side.

Periods of drought, like that extending through the summer of 1936, and probably also prairie fires aid in maintaining the above described relationships of the ecological associations in the Bird Creek region. The droughts prevent the forest from occupying the grasslands by killing numerous trees in the forest associations, thereby reducing the extent and density of these associations.

Since the Bird Creek region is intermediate in position and in climate between the eastern deciduous forest and the Great Plains grasslands, and since ecological associations of both maintain their individual characteristics here, it is not strictly referable to either. However, it is theoretically referable to the eastern deciduous forest, since the oak—hickory association, which is here encroaching slightly on the grassland associations, is considered the regional climax. It seems doubtful, however, that under the present climatic conditions the oak—hickory association would ever replace the grassland associations. Severe droughts, to which the region occasionally is subjected, restrict the spread of forest associations by killing the trees, and the constantly high wind velocity probably reduces, through evaporation, the amount of moisture available for plant growth to much less than the average annual rainfall would seem to indicate.

Ecological Distribution of the Mammals

Several of the species of mammals in the Bird Creek region are widely distributed forms that range over many biotic areas in North America. The other species of mammals in the region have as their respective areas of greatest abundance several nearby biotic areas.

Twelve of the 31 species of mammals definitely recorded from the Bird Creek region have as their area of greatest abundance the eastern deciduous forest, and 4 have the Great Plains grasslands. Three have the Gulf coastal plain as their area of greatest abundance, and one has the tall-grass prairies. One species has boreal North America as its area of greatest abundance, and one has the desert mountain ranges of the southwestern United States.

Seven of the 12 eastern deciduous forest species in the Bird Creek region are confined there to forest associations, and one occurs in an association intermediate between the forest and grassland. These species extend westward to the limits of the forest associations and there stop:

Didelphis virginiana	*Sciurus carolinensis*
Cryptotis parva	*Sciurus niger*
Blarina brevicauda	*Glaucomys volans*
Pipistrellus subflavus	*Pitymys nemoralis*

Four of these species, the opossum *(Didelphis virginiana)*, gray-squirrel *(Sciurus carolinensis)*, fox-squirrel *(Sciurus niger)*, and flying-squirrel *(Glaucomys volans)*, are semi-arboreal. The pipistrelle *(Pipistrellus subflavus)* is a cave-inhabiting form, which probably is largely limited by the absence of caves from the eastern Great Plains. Two non-arboreal species, the Carolina shrew *(Blarina brevicauda)* and pine vole *(Pitymys nemoralis)*, are confined almost entirely to the mesic floor of the oak—elm association. The little shrew *(Cryptotis parva)* occurs in the sumac—grama association in the Bird Creek region, and it commonly occurs also in grassy fields throughout its range. Therefore, it seems probable that some factor other than the absence of forest associations limits its western distribution.

Four eastern deciduous forest species occur occasionally in grassland

associations in the Bird Creek region and extend beyond the western limits of the forest associations. These species are:

Scalopus aquaticus	*Neotoma floridana*
Peromyscus leucopus	*Sylvilagus floridanus*

The mole *(Scalopus aquaticus)* extends out into the Great Plains along the streams farther than does the lowland forest. Soil that can be worked easily is an essential factor in the distribution of this species, and east-west stream valleys are highways by which the species extends out into the Great Plains. In western Oklahoma this species is abundant in the sand dunes adjoining the larger streams, where the characteristic plants are sand-inhabiting species with western affinities.

The wood-mouse *(Peromyscus leucopus)* in the Bird Creek region occurs occasionally in the sumac—grama association, but it otherwise is confined to the forest associations. The species extends westward with the oak—elm association along the flood-plains of the streams. However, it extends beyond the western limits of this association and inhabits brushy situations in the grasslands of western Oklahoma. West of the Great Plains the species occurs in brush and forest associations.

The Florida woodrat in the southeastern states is more arboreal than in the western part of its range. In the Bird Creek region the species occasionally nests in trees, although it most frequently is associated with rock outcrops. The woodrat extends westward along the stream valleys, and in Oklahoma it apparently does not extend beyond the western limits of eastern deciduous forest associations. In western Kansas the species is in part saxicolous and is said also to live on the open, grassy plains.

The Florida cottontail is abundant in the Bird Creek region in the several forest associations and in the sumac—grama association, which is intermediate between the deciduous forest associations and those of the Great Plains grasslands. It also occurs occasionally in the Great Plains grassland associations. The species is distributed westward along the stream valleys and extends beyond the western limits of the eastern deciduous forest associations. In western Oklahoma it is abundant in the sand dunes adjoining the larger streams.

The 3 Gulf coastal plain species in the Bird Creek region are a pocket-gopher *(Geomys breviceps)*, a cotton-rat *(Sigmodon hispidus)*, and the swamp rabbit *(Sylvilagus aquaticus)*.

The pocket-gopher occurs in the Bird Creek region in grassland associations and in the oak—elm association. Soil sufficiently deep for burrowing is an important factor in the distribution of this species. Its westward distribution follows along the stream valleys, for in western Oklahoma it is largely confined to them. In northeastern Oklahoma the species approaches the northern limits of its known range.

The cotton-rat occurs in the Bird Creek region in all of the ecological associations having a fairly heavy ground cover, and in times of great abundance it moves out into the arid grassland type of association. The species probably extends westward in the stream valleys, but the extent of its western

distribution is not known. It approaches the northern limits of its known range in northeastern Oklahoma.

The swamp-rabbit enters the Bird Creek region through the valley of the Arkansas River. In the Bird Creek region this species is confined to forest associations of the flood-plain, and so far as known it occurs in no other associations in northeastern Oklahoma. The species extends westward along the streams at least to the western edge of the Osage Savanna biotic district. It reaches the northern limit of its range in southeastern Kansas.

None of the Gulf coastal plain species found in the Bird Creek region are limited in their northern distribution by any observable physical barrier, and the northern limits of none of them coincide with any marked change in the vegetation or physical environment.

The only species in the Bird Creek region that has the tall-grass prairies as its area of greatest abundance is the prairie vole *(Microtus ochrogaster)*. It occurs in the bluejoint—switchgrass association in the Bird Creek region, and apparently approaches the southwestern limits of its range there. It probably does not extend westward beyond the limits of the tall-grass prairie type of association, and its southern limit possibly is determined by the maximum summer temperature, as stated in the annotated list.

The 4 species in the Bird Creek region having the Great Plains grasslands as their area of greatest abundance are the prairie spotted skunk *(Spilogale interrupta)*, thirteen-lined spermophile *(Citellus tridecemlineatus)*, plains pocket-mouse *(Perognathus hispidus)*, and gray harvest-mouse *(Reithrodontomys montanus)*. All of these species range widely northward and southward in the Great Plains. The pocket-mouse and harvest-mouse are confined in the Bird Creek region to the grama—beardgrass, plum thicket, and sumac—grama associations and apparently reach their eastern limits at the eastern limits of the ecological associations representative of the Mixed-grass Plains biotic district. The prairie spotted skunk, which occurs in the Bird Creek region in both grassland and forest associations, extends northeastward for some distance into the tall-grass prairies, but so far as known it does not cross the Mississippi River. The thirteen-lined spermophile, which ranges over most of the Great Plains grasslands and which in the Bird Creek region occurs in both mixed-grass and tall-grass associations, extends eastward in the tall-grass prairies to northern Ohio.

Three species that are widely distributed in western North America occur in the Bird Creek region, into which they range from the Great Plains grasslands. These species are the coyote *(Canis latrans)*, deer-mouse *(Peromyscus maniculatus)*, and black-tailed jackrabbit *(Lepus californicus)*. The coyote is known to occur in the grama—beardgrass and sumac—grama associations in the Bird Creek region. It ranges eastward in the tall-grass prairies, but so far as known it does not occur in forest associations in eastern Oklahoma. The deer-mouse is widely distributed in the Great Plains grasslands. In the Bird Creek region it occurs in both the mixed-grass and tall-grass type of associations. The species extends eastward in the tall-grass prairies and also inhabits the northern part of the eastern deciduous forest and the forests of

the Appalachian Mountains. It does not extend eastward from the Great Plains grasslands into the ecological associations of the central and southern parts of the eastern deciduous forest. The jackrabbit reaches its eastern limit at approximately the eastern limits of the mixed-grass type of associations. It does not occur in the ecological associations of the tall-grass prairies nor in those of the eastern deciduous forest. However, the destruction of these associations in large areas and their replacement by cultivated fields or barren pasture land have permitted the jackrabbit to extend its range some distance eastward in historic time.

One species of which the area of greatest abundance is boreal North America occurs in the Bird Creek region. This is the jumping-mouse *(Zapus hudsonius)*, which is at approximately the southern limit of its known range. The species extends southward along the Atlantic coast to Raleigh, North Carolina, but there are no known records of the jumping-mouse from the states intervening between North Carolina and Oklahoma. The jumping-mouse occupies brushy situations along streams in the northern Great Plains, and the species probably extends along north-south stream valleys into the Bird Creek region, where it is recorded from the lowland thicket association. A possible course would be by way of the Missouri, Osage, and Grand river systems.

One species that has as its area of greatest abundance the desert mountain ranges of southwestern North America occurs in the Bird Creek region. This is the brush-mouse *(Peromyscus boylii)*, which occupies brushy and rocky habitats in many parts of Mexico and the southwestern United States. Wooded and rock-bordered stream valleys that cross the Great Plains grasslands probably are highways for the eastward distribution of this species. The brush-mouse, which is confined to the ravine forest association in the Bird Creek region, extends eastward into the Ozark biotic district of southwestern Missouri and northwestern Arkansas, where it occupies an association similar to the one to which it is confined in the Bird Creek region.

Six species that range over a large part of North America occur in the Bird Creek region:

Lasiurus borealis	*Mustela vison*
Eptesicus fuscus	*Mephitis mephitis*
Procyon lotor	*Ondatra zibethica*

The red bat *(Lasiurus borealis)* and the big brown bat *(Eptesicus fuscus)* are inhabitants of forest associations. For this reason they are absent from much of the Great Plains, although they occur both east and west of the plains. The striped skunk *(Mephitis mephitis)* in the Bird Creek region ranges over most of the associations, as it does in most other regions in which it occurs. The species is not restricted to any particular type of ecological associations, possibly because of its specialized organs of defense, which make it more or less independent of the physical and vegetational features of the environment for protection. The raccoon *(Procyon lotor)*, mink *(Mustela vison)*, and muskrat *(Ondatra zibethica)* are inhabitants of the aquatic and littoral associations and range along streams into many biotic areas of North

America. The most important factor in the distribution of these forms apparently is the presence of water, and if water is present they are tolerant of many kinds of environments. All range across the Great Plains along the streams and are widely distributed along streams both east and west of the plains.

The several species of mammals in the Bird Creek region have various areas of greatest abundance, but the most important are the eastern deciduous forest, the Gulf coastal plain, and the Great Plains grasslands. Several species of wide distribution in western North America occur in the region and form with the Great Plains grassland mammals an important element of grassland species. Others range over most of North America and occur in many biotic areas.

The northern limits of Gulf coastal plain species that occur in the Bird Creek region and the southern limits of boreal and tall-grass prairie species that are present there are not correlated with any noticeable change in the physical environment.

A species tends to occupy, in the Bird Creek region, ecological associations similar to those it occupies in its area of greatest abundance. Seven of the 12 eastern deciduous forest species in the Bird Creek region are confined to forest associations, and one of the Gulf coastal plain species also is confined to forest associations. Four Great Plains grassland species and 3 species of wide distribution in western North America are confined in the Bird Creek region to Great Plains grassland associations. The one tall-grass prairie species in the Bird Creek region is recorded in the region only from a tall-grass prairie association. The southwestern species in the Bird Creek region is confined to the ravine forest association, and the species of which the area of greatest abundance is boreal North America is only recorded from the lowland thicket association.

While there is a tendency, as shown above, for most species in the ecotone between the eastern deciduous forest and the Great Plains grasslands to be restricted to associations similar to those they occupy in their respective areas of greatest abundance, some, in this transition area, spread out into other types of associations.

Four of the eastern deciduous forest species in the Bird Creek region, though most abundant in forest associations, occur here occasionally in grassland associations, and one species has been recorded in the region only from a grassland association. Three of the species in the Bird Creek region that either are widely distributed in western North America or have the Great Plains grasslands as their area of greatest abundance occur here in the tall-grass prairie type of association, and another species occurs also in forest associations. One of the Gulf coastal plain species in the Bird Creek region occurs here in grassland associations, although it is most abundant in the forest associations, and another occurs in the region principally in grassland associations, although it is present also in forest associations.

Some of the species that occur in the transition area in associations unlike

those they occupy in their respective areas of greatest abundance extend beyond the geographic limits of their respective association types.

Four of the eastern deciduous forest species and one of the Gulf coastal plain species of the Bird Creek region extend westward into the Great Plains grasslands. Two Great Plains grassland species and 2 species of wide distribution in western North America that occur in the Bird Creek region extend northeastward into the tall-grass prairies.

There is a tendency for most of the species to be changed into other races as they extend into areas where they occupy habitats different from those they inhabit in their respective areas of greatest abundance.

The 4 eastern deciduous forest species that extend westward into the Great Plains grasslands are represented there by distinct races. The mole of western Oklahoma is paler than the races that occur in the eastern deciduous forest and constitutes the race *Scalopus aquaticus intermedius*. The mole of the Bird Creek region is intermediate in color between the moles of the eastern deciduous forest and the western race, although it is referable to the latter.

The wood-mouse of the Bird Creek region is of the race *Peromyscus leucopus noveboracensis*, which occupies much of the northern half of the eastern deciduous forest. In the Mixed-grass Plains district this race is replaced by the paler colored race *texanus*.

The Florida woodrat of the Bird Creek region is of the race *Neotoma floridana baileyi*, which is characteristic of the broad ecotone between the eastern deciduous forest and the Great Plains grasslands. This race mostly is associated with rock outcrops along the edges of the stream valleys, although it also occurs away from rocks in the flood-plain forest. To the east it intergrades with the races *rubida* and *illinoensis*, which occupy the lowlands of the lower and middle Mississippi Valley. In western Kansas *baileyi* supposedly intergrades with the pale-colored race *campestris*, which inhabits there the Great Plains grasslands. In western Oklahoma the Great Plains grasslands are occupied by *Neotoma micropus*, which belongs to the same species group.

The cottontail of the Bird Creek region is of the race *Sylvilagus floridanus alacer*, which centers in the Ozark district. It is replaced in western Oklahoma by the paler racer *llanensis* (Blair, 1938).

The one Gulf coastal plain species in the Bird Creek region that extends westward beyond the limit of forest associations is the pocket-gopher *(Geomys breviceps)*. It is represented in the Bird Creek region by the race *breviceps*, which occurs in alluvial soil in Louisiana and eastern Texas and Oklahoma. In central Oklahoma and Texas it intergrades with the paler colored race *llanensis*, which inhabits stream valleys in western Oklahoma and northwestern Texas.

One Great Plains grassland species and 2 species of wide distribution in western North America that enter the Bird Creek region from the Great Plains grasslands are represented in the tall-grass prairies by distinct races. The thirteen-lined spermophile of the Bird Creek region is of the race *Citellus tridecemlineatus texensis*, which ranges over the Mixed-grass Plains district.

Northeastward it intergrades with the race *tridecemlineatus,* which occupies the tall-grass prairies. The coyote of the Great Plains grasslands in Oklahoma is of the race *Canis latrans nebrascensis* according to Jackson and Warfel (1933, 65). This is replaced in the tall-grass prairies by the race *latrans.* The deer-mouse of the Bird Creek region is closely related to the race *Peromyscus maniculatus ozarkiarum,* of the southern Ozarks, and to *bairdii* of the tall-grass prairies, but it is best referred to the former race. It intergrades gradually westward with a paler colored form that resembles the race *nebrascensis* of western Kansas and Nebraska.

Two species of the Bird Creek region that are widely distributed in North America are represented by distinct races in the tall-grass prairies and in the Great Plains grasslands. One of these species, the striped skunk *(Mephitis mephitis),* also is represented in the nearby eastern deciduous forest by a distinct race. The striped skunk of the Bird Creek region is referable to this race, *mesomelas,* which ranges through Louisiana and Arkansas and westward through the eastern half of Oklahoma and Texas. It apparently intergrades in western Oklahoma with the race *varians* of the Great Plains grasslands. Northeastward, it intergrades with the race *avia* of the tall-grass prairies (Howell, 1901, 30). The other widely distributed species is the muskrat *(Ondatra zibethica),* which is represented in the Bird Creek region by the race *cinnamomina.* This race is widely distributed in the Great Plains and intergrades with the race *zibethica* at the approximate border between the Great Plains grasslands and the tall-grass prairies (Hollister, 1911, 31).

From the discussion above, it is evident that there is a tendency for a species to become modified as it extends beyond the types of habitats that it occupies in its area of greatest abundance. These modifications often are sufficiently great that they form the basis for the recognition of subspecies.

Summary

The Bird Creek region of northeastern Oklahoma is intermediate in position between the eastern deciduous forest and the Great Plains grasslands, and is, therefore, part of an area that is neither predominantly grassland nor forest. The ecological associations are related in part to those to the east in the eastern deciduous forest and tall-grass prairies, and in part to those to the west in the Great Plains grasslands.

The Bird Creek region climatically is near the border line between the humid and arid divisions of North America, and edaphic factors control the local occurrence of the ecological associations. As a result of this edaphic control, there is an alternation and interdigitation of eastern forest and western grassland associations.

Since the Bird Creek region is intermediate in position and climate between the eastern deciduous forest and the Great Plains grasslands, and is an area in which the ecological associations of those biotic areas meet and maintain their individual characteristics, it is not strictly referable to either biotic

area. However, the oak—hickory association is considered the regional climax, and for that reason the Bird Creek region theoretically should be included with the eastern deciduous forest. It is improbable, however, that under the present climatic conditions, the forest would ever occupy the Bird Creek region to the exclusion of the grassland associations. Periods of dry years, like that culminating in the great drought of 1936, aid in preventing the forest from spreading out over the grasslands.

Six of the species of mammals in the Bird Creek region range over most of North America, and 3 species are widely distributed in western North America. Twelve of the species have as their area of greatest abundance the eastern deciduous forest, and 4 the Great Plains grasslands. Three species in the region have as their area of greatest abundance the Gulf coastal plain, one the tall-grass prairies, one boreal North America, and one species the desert mountain ranges of the southwestern United States.

As a rule the species of mammals occupy in the Bird Creek region ecological associations that are similar to those they occupy in their respective areas of greatest abundance. Not all of the species, however, are restricted to their own association types in this transition area. Five eastern deciduous forest species and 2 Gulf coastal plain species occur occasionally in grassland associations in the Bird Creek region. Four species that range into the Bird Creek region from the Great Plains grasslands are not restricted in the region to the Great Plains grassland associations, but occur also in the association representative of the tall-grass prairies. One of the 4 species occurs also in forest associations in the region.

The species that occur in the Bird Creek region outside of the types of associations they occupy in their respective areas of greatest abundance also extend beyond the geographic limits of their particular association types. Four of the eastern deciduous forest species and one of the Gulf coastal plain species extend well beyond the western limits of the forest associations. The four grassland species that range into the Bird Creek region from the Great Plains grasslands extend a considerable distance into the tall-grass prairies.

There is a tendency for the species that extend beyond the limits of their respective association types to be modified in so doing. The 4 eastern deciduous forest species that extend into the Great Plains grasslands from western Oklahoma and Kansas differ there from their representatives in eastern Oklahoma. Three of the grassland species that extend from the Great Plains grasslands into the tall-grass prairies differ in the 2 places.

The changes that species undergo in passing from the habitats that they occupy in their respective areas of greatest abundance into different types of habitats generally are sufficiently great that they form the basis for the recognition of subspecies. The 4 eastern deciduous forest species and the one Gulf coastal plain species of the Bird Creek region that extend into the grasslands of western Oklahoma are represented there by distinct subspecies. Three of the 4 species that occur in both the Great Plains grasslands and in the tall-grass prairies are represented in the 2 places by different subspecies.

REFERENCES

BLACK, J. D. 1935—A new race of *Peromyscus maniculatus* from Arkansas. Journ. Mammalogy **16**:144-145.

BLAIR, W. F. 1936—The nine-banded armadillo in northeastern Oklahoma. Journ. Mammalogy **17**:293-294.

———1937—The burrows and food of the prairie pocket mouse. Journ. Mammalogy **18**:188-191.

———1938—A new race of the eastern cottontail from the Texas Panhandle. Occas. Pap., U.M.M.Z., 380:1-3.

BLAIR, W. F. AND T. H. HUBBELL. 1938—The biotic districts of Oklahoma. Amer. Midl. Nat. **20**(2):425-454.

BOLLINGER, C. J. 1925—The eastern boundary of the Great Plains in north central Oklahoma. Proc. Okla. Acad. Sci. **5**:123-124.

BRUNER, W. E. 1931—The vegetation of Oklahoma. Ecol. Monogr. **1**:99-188.

CLEMENTS, F. E. 1920—Plant indicators. Carnegie Inst. Wash., Publ. **290**:1-388.

DICE, L. R. 1922—Some factors affecting the distribution of the prairie vole, forest deer mouse, and prairie deer mouse. Ecology **3**:29-47.

———1931—Methods of indicating the abundance of mammals. Journ. Mammalogy **12**:376-381.

GRINNELL, JOSEPH. 1914—An account of the mammals and birds of the lower Colorado Valley. Univ. of Calif. Publ. in Zool. **12**:51-294.

HOLLISTER, N. 1911—A systematic synopsis of the muskrats. U. S. Dept. Agric., Bur. Biol. Surv., North Amer. Fauna **32**:1-47.

HOWELL, A. H. 1901—Revision of the skunks of the genus *Chincha*. U. S. Dept. Agric., Div. Biol. Surv., North Amer. Fauna **20**:1-47.

JACKSON, H. H. T AND H. E. WARFEL. 1933—Notes on the occurrence of mammals in the regions adjacent to the salt plains of northwestern Oklahoma. Publ. Univ. Okla. Biol. Surv. **5**:65-72.

MILLER, G. S. 1924—List of North American recent mammals. Smiths. Inst. Bull. **128**:1-673.

NELSON, E. W. AND E. A. GOLDMAN. 1930—Six new raccoons of the *Procyon lotor* group. Journ. Mammalogy **11**:435-459.

OKLAHOMA GAME AND FISH COMMISSION. 1936—Biennial report. Oklahoma City. 1-72.

OKLAHOMA GEOLOGICAL SURVEY. 1930—Oil and gas in Oklahoma. Okla. Geol. Surv. Bull. **40**(3):1-663.

SNIDER, L. C. 1917—Geography of Oklahoma. Okla. Geol. Surv. Bull. **27**:1-325.

TOWNSEND, M. T. 1935—Studies on some of the small mammals of central New York. Roosevelt Wild Life Annals **4**:1-120.

WEAVER, J. E. AND F. W. ALBERTSON. 1936—Effects of the Great Drought on the prairies of Iowa, Nebraska, and Kansas. Ecology **17**:567-639.

WEAVER, J. E. AND F. E. CLEMENTS. 1929—Plant ecology. New York. 1-520.

Wildlife Mortality on Iowa Highways

Thos. G. Scott[1]

Incidental to travel in Iowa while serving as wildlife specialist for the Extension Service, of Iowa State College, the writer, on occasions, found it possible to investigate wildlife mortality on paved highways. The data were gathered primarily for use as possible indices to distribution, population, and lateral movement of mammals. As little additional effort proved necessary, observations were made on all vertebrate forms.

With the purpose of preserving the principal objectives, a technique for gathering the information was developed. Observations were begun at a distinct landmark, as a highway junction, city limit, or county line. The mileage reading was recorded at the starting point and again at the place where each casualty was noted, thus each record has a definite geographic location. No observations were attempted unless circumstances permitted low-speed travel and frequent stops for in spite of thoroughness some victims were overlooked. Mileage and casualties were recorded only for rural sections; victims were listed only when found on the highway or within 1 yard of it. In an attempt to limit the casualty age class no record was made of animals not subject to identification.

Casualty notations are available for all months of the year, beginning in May, 1936 and concluding in April, 1937. During this period records were preserved for a rural distance of 2,944.1 miles[2] distributed over 43 counties. High mortality of wildlife was expected in Iowa because the straight smooth roadways and the law permit travel at high rates of speed in rural sections.

Casualties totaling 1,239, or approximately 0.429 to a mile, were noted. The length of time that the vertebrate body remained on the highway after death varied with the species, but recognizable forms were not usually found after 4 days exposure. A reasonable casualty age class was thus established. It may then be assumed that approximately 365 divided by 4 times 0.429, or 39.1462, is the number of vertebrate animals killed in a year on 1 mile of high-speed roadway in Iowa. There are approximately 4,820 miles of hard-surface highway in Iowa similar to that on which the investigation was made, and these comprise about one-sixth of the total number of miles of all roads in the State. The approximate annual toll of wildlife on the improved highways of Iowa can be obtained by multiplying the annual casualty rate of 1 mile (39.1462) by 4, 820. These numbers no doubt are conservative, as available information indicates that possibly 10 per cent of the casualties went unrec-

1 Journal Paper No. J578 of the Iowa Agricultural Experiment Station. Project No. 598. In cooperation with the U. S. Biological Survey, the American Wildlife Institute, and the Iowa State Conservation Commission.

2 Credit is due R. C. Fye, of the Iowa State Highway Commission, for checking the accuracy of the rural mileage.

TABLE 1.—Monthly distribution of mileage and casualties.

	1936								1937				
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Mileage	322.9	678.9	160.0	450.0	175.5	254.1	224.6	63.5	247.5	84.4	195.5	87.2	2,944.1
Casualties per mile	.263	.726	.538	.684	.484	.362	.071	.173	.044	.130	.072	.298	0.429
No. of casualties	85	493	86	309	85	92	16	11	11	11	14	26	1,239

TABLE 2.—Amphibian casualties.

Name	1936								1937				
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
					1								1
Tiger salamander[1]					.006								.0003
		1											1
Common toad		.001											.0003
		1		8+2									9+
Frogs		.001											

[1] Numbers in upper row of line represent the number of casualties; numbers in lower row, the casualties per mile.

[2] Record made after a storm, 8 definitely of the leopard frog *(Rana pipiens)*, plus an unusual number (estimated at 10 per square yard) of leopard frogs, cricket frogs *(Acris crepitans)*, and probably other species distributed over half a mile of highway adjacent to a large marsh.

orded, because of sun glare, size and color of the animal, tall grass, high wind, or snow. Among the 1,239 animals killed, 57 species were represented: 3 amphibians, 8 reptiles, 16 mammals, and 30 birds.

An attempt was made to determine the circumstances under which wildlife meets accidental death on the highway. It was found that the greater number of animals were killed wherever favorable wildlife environment intersected high-speed roadways. As each variation in environment produced a corresponding variation in the species and numbers of wildlife casualties, one is led to believe that highway mortality of some species may be subject to control. Once wildlife had access to the highway, subsidiary factors produced variations in the rate of mortality. Most of these factors were found to be conditions of weather. Sudden and severe changes in temperature produced fluctuations in the number of animals killed, apparently because of their increased or decreased activity, depending on the species. Rain affected the mortality rate, possibly because it slowed and reduced traffic, or because it produced an increase or decrease in the activity of the animals. The activity of amphibians during and immediately after storms resulted in an increase in the mortality of this group. Puddles of rain water along the highway proved hazardous to the birds coming for or returning from a drink or a bath. High wind caused a reduction in mortality, apparently because most species remained within the protection of cover. High winds were disadvantageous to some birds, notably the English sparrows *(Passer domesticus domesticus)*, because they reduced the efficiency of their flight. In some instances snow and ice reduced speed and traffic on the highways to the point where wildlife mortality was practically eliminated. At other times these conditions produced an increase in mortality, as the animals were encouraged to come to the cleared highway shoulders for food. Curvature of the highway checked high-speed travel and reduced casualties except among the slow-moving species. Mannerisms characteristic of certain forms of wildlife were frequently found to be the cause of death on the highway. Mention of these is made in the annotated list.

The data gathered provide some basis for estimating the highway mortality of game species, a subject of frequent discussion among conservationists. Despite the fact that the ring-necked pheasant *(Phasianus colchicus torquatus)* population in Iowa was greatly limited during the period of this investigation (Green and Beed, 1937), the killing of these birds was recorded. Investigations were conducted, through all months of the year, along 1,146 rural miles, in 25 counties of typical pheasant range. The killing of 28 pheasants, or 0.0244 to the mile, was recorded. This indicates an annual kill of 0.0244 (365 ÷ 4), or 2.2265, birds on each mile of improved highway in pheasant range. It is not possible to estimate the acreage from which this toll was taken as the seasonal range of pheasants in Iowa has not been determined.

The population of cottontails *(Sylvilagus floridanus mearnsii)* was also low when these investigations were made; nevertheless, in 2,944.1 miles, 90 casualties (0.0305 to the mile) were noted. This indicates an annual mortality rate of 2.7831 cottontails to the mile. If the yearly range of the cotton-

tail is assumed to be half a mile, this toll would be effective on 640 acres for a mile of highway.

Fox squirrels *(Sciurus niger rufiventer)* have moved into isolated farm wood lots and shelterbelts, many of which are near highways. This adaptation has apparently increased the highway mortality of this species, for of the 25 dead fox squirrels noted, 20 were in the more open prairie counties near farm shelterbelts and wood lots.

The toll of less desirable species was equally as great. For the 2,944.1 miles covered, 432 English sparrows, or 0.1467 to a mile, were recorded. Possibly 13.3863 may be killed annually for each mile of improved highway in Iowa. Of the striped ground squirrels *(Citellus tridecemlineatus tridecemlineatus)* 127 casualties were listed. Agricultural operations caused this species to be more road inhabiting. The roadway mortality of other species may be seen in the charts and annotated list.

The nomenclature and systematic sequence of the amphibians and reptiles, are according to Pratt (1935), of the birds, according to the American Ornithologists' Union check-list (1931), of the mammals, according to Miller (1924), except where changes have been made. Tables are included for all species, giving the number of casualties per month and the rate per mile. Special phases, as sex ratio, color, and age class, are also treated. The county is used as the unit of distribution and note is made of it in the annotation. In reading the annotated list it is well to bear in mind that the mileage varied in each county and that investigations were conducted in only 43 of Iowa's 99 counties. The value of the distributional records and the indication of populations as reflected by casualty rate will no doubt increase with age.

To facilitate interpretation of the county casualty rate to the mile, a list of the counties and the rural miles traveled in each has been prepared: Adair, 8.2; Boone, 154.0; Bremer, 46.2; Butler, 48.2; Carroll, 23.2; Cass, 66.6; Cerro Gordo, 30.8; Clay, 60.9; Clayton, 88.1; Dallas, 48.8; Delaware, 22.5; Dickinson, 28.8; Emmet, 5.0; Fayette, 73.2; Floyd, 36.9; Franklin, 72.5; Green, 23.0; Guthrie, 38.2; Hancock, 146.1; Hamilton, 329.1; Hardin, 76.8; Harrison, 69.9; Howard, 23.0; Jasper, 14.0; Kossuth, 47.2; Linn, 21.5; Mahaska, 12.8; Madison, 21.7; Marion, 12.8; Marshall, 15.5; Mills, 19.0; Mitchell, 18.6; Montgomery, 31.0; O'Brien, 21.4; Palo Alto, 35.5; Polk, 187.2; Pottawattamie, 35.8; Story, 607.0; Warren, 20.7; Webster, 26.2; Winnebago, 41.6; Winneshiek, 52.4; and Wright, 182.2.

Annotated List of Casualties

Amphibians

Tiger salamander, *Ambystoma tigrinum* (Green).

Distribution by county: Hamilton, 1.

This record was made September 27, 1936, at which time there appeared to be considerable movement of this species in search of a place for hibernation.

Common toad, *Bufo americanus* Holbrook.

Distribution by county: Emmet, 1.

Leopard frog, *Rana pipiens* Schreber.

Distribution by county: Clayton, 8; Hamilton (see footnote, table 2); Polk, 1.

Reptiles

Blue racer, *Coluber constrictor flaviventris* Say.
Distribution by county: Marion, 1; Story, 1.

Fox snake, *Elaphe vulpina* (Baird and Girard).
Distribution by county: Fayette, 1; Guthrie, 1; Webster, 1.

Bull snake, *Pituophis sayi* (Schlegel).
Distribution by county: Adair, 1; Dallas, 1; Guthrie, 1; Jasper, 2; Madison, 1; Marion, 5; Polk, 3; Story, 6; Warren, 1.

Plains garter snake, *Thamnophis radix* (Baird and Girard).
Distribution by county: Boone, 1; Hamilton, 3.

Guthrie (1926, p. 186) refers to this snake as the "most common and widely distributed species" in Iowa. If roadside casualties are indicative of population, it would appear that the above statement was more nearly true of the bull snake at the time of this investigation.

Red-barred garter snake, *Thamnophis sirtalis parietalis* (Say)
Distribution by county: Boone, 1; Fayette, 1; Hamilton, 2; Mahaska, 1.
Three of this species and three of the plains garter snake were recorded from October 15 to 19. This suggests a lateral movement preparatory to hibernation.

Common snapper, *Chelydra serpentina* (Linnaeus).
Distribution by county: Clay, 1; Delaware, 1; Hamilton, 2; Story, 1; Polk, 3.
All were recorded between 15 and 50 yards from water.

Ornate box turtle, *Terrapene ornata* (Agassiz).
Distribution by county: Clayton, 1; Hamilton, 1.

Painted turtle, *Chrysemys picta* (Schneider).
Distribution by county: Cerro Gordo, 2; Clay, 2; Fayette, 1; Floyd, 1; Greene, 1; Hamilton, 6; Winnebago, 1.

All were found less than 40 yards from water. Of the 14 listed, 13 occurred during May and June, indicating a lateral movement during the breeding season. A similar activity is apparent from the records of the common snapper.

Birds

Eastern sparrow hawk, *Falco sparverius sparverius* (Linnaeus).
Distribution by county: Boone, 1.

European partridge, *Perdix perdix perdix* (Linnaeus).
Distribution by county: Palo Alto, 1.

Eastern bobwhite, *Colinus virginianus virginianus* (Linnaeus).
Distribution by county: Story, 1.

Ring-necked pheasant, *Phasianus colchicus torquatus* (Gmelin).
Distribution by county: Boone, 4; Bremer, 2; Butler, 6; Clay, 1; Clayton, 1; Dickinson, 1; Franklin, 2; Hamilton, 8; Hancock, 1; Hardin, 3; Kossuth, 3; O'Brien, 1; Palo Alto, 2; Story, 3; Webster, 1; Winnebago, 5.

Of the 44 recorded, 19 were males, 17 females, and 8 young. It appears of some significance that eight of the females were found in June.

Sora, *Porzana carolina* (Linnaeus)
Distribution by county: Story, 1.
This was found on September 19, near a roadside pothole.

Eastern and western mourning dove, *Zenaidura macroura* sbsp. *carolinensis* and *marginellla.*

Distribution by county: Boone, 2; Cass, 1; Clayton, 2; Dallas, 2; Hamilton, 1; Harrison, 1; Linn, 1; Polk, 6; Pottawattamie, 2; Story, 8.

TABLE 3.—Reptile casualties.

Name	1936								1937				Total
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
Blue racer[1]	1 .003	1 .001											2 .0007
Fox snake		1 .001		1 .002		1 .004							3 .0010
Bull snake	10 .031	5 .007	2 .013	1 .002	3 .017								21 .0071
Plains garter snake				1 .002		3 .012							4 .0014
Red-barred garter snake	1 .003			1 .002		3 .012							5 .0017
Common snapper	1 .003	6 .009	1 .006										8 .0027
Ornate box turtle				2 .004									2 .0007
Painted turtle	4 .012	9 .013	1 .002										14 .0048

1 Numbers in upper row of line represent the number of casualties; numbers in lower row, the casualties per mile.

Yellow-billed cuckoo, *Coccyzus americanus americanus* (Linnaeus).
Distribution by county: Story, 2.

Eastern screech owl, *Otus asio naevius* (Gmelin).

Distribution by county: Boone, 2; Clayton, 1; Dickinson, 2; Guthrie, 1; Hamilton, 6; Polk, 1; Pottawattamie, 1; Story, 7; Wright, 2.

Several screech owls were seen to pass in front of the writer's car at night. Intent on hunting, the owls were probably blinded and swerved into passing automobiles. Of the 23 screech owl casualties, 12 were in the red phase of plumage and 11 in the gray.

Long-eared owl, *Asio wilsonianus* (Lesson).

Distribution by county: Boone, 1.
This was observed near a farm wood lot on June 22.

Northern flicker, *Colaptes auratus luteus* (Bangs).

Distribution by county: Boone, 1; Bremer, 1; Butler, 2; Clay, 1; Dickinson, 1; Fayette, 3; Franklin, 1; Guthrie, 2; Hancock, 1; Kossuth, 2; Linn, 1; Palo Alto, 1; Pottawattamie, 1; Story, 3.

Red-headed woodpecker, *Melanerpes erythrocephalus* (Linnaeus).

Distribution by county: Adair, 1; Boone, 7; Bremer, 1; Butler, 6; Cass, 1; Clay, 2; Clayton, 2; Dallas, 2; Delaware, 2; Dickinson, 8; Fayette, 4; Franklin, 1; Greene, 1; Guthrie, 7; Hamilton, 6; Hancock, 3; Hardin, 3; Harrison, 1; Kossuth, 2; Linn, 3; Mahaska, 3; Marion, 1; Palo Alto, 2; Polk, 10; Pottawattamie, 3; Story, 37; Warren, 2; Winneshiek, 1; Wright, 3.

Of the 115 records for this species, 24 were of young birds, and all these were noted in August. The greatest mortality occurred in June, indicating the increased activity of the nesting period.

Hoyt's horned lark, *Otocoris alpestris hoyti* (Bishop).
Distribution by county: Story, 1.

Prairie horned lark,*Otocoris alpestris praticola* (Henshaw).
Distribution by county: Clay, 1.
This record was made on June 7.

Barn swallow, *Hirundo erythrogaster* Boddaert.
Distribution by county: Fayette, 1; Butler, 1.

Black-capped chickadee, *Penthestes atricapillus atricapillus* (Linnaeus).
Distribution by county: Guthrie, 1.

Western house wren, *Troglodytes aedon parkmani* Audubon.
Distribution by county: Palo Alto, 1.

Catbird, *Dumetella carolinensis* (Linnaeus).
Distribution by county: O'Brien, 1.

Brown thrasher, *Toxostoma rufa* (Linnaeus).

Distribution by county: Boone, 3; Dickinson, 1; Hancock, 1; Kossuth, 1; Polk, 2; Story, 3.

All records of this species were made in the vicinity of shrubs and low-growing trees.

Eastern robin, *Turdus migratorius migratorius* Linnaeus.
Distribution by county: Boone, 2; Clay, 1; Fayette, 1; Hamilton, 1; Kossuth, 1; O'Brien, 1; Palo Alto, 1; Polk, 2; Story, 6; Warren, 1.

Eastern bluebird, *Sialia sialis sialis* (Linnaeus).
Distribution by county: Story, 1.

Migrant shrike, *Lanius ludovicianus migrans* Palmer.
Distribution by county: Dallas, 1; Story, 1.

TABLE 4.---Bird casualties

Name	1936								1937				
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Eastern sparrow hawk[1]					1								1
					.006								.0003
European partridge		1											1
		.001											.0003
Eastern bobwhite						1							1
						.004							.0003
Ring-necked pheasant	2	14		14	4	3			1		1	3	44
	.006	.021		.031	.023	.012			.004		.006	.034	.0149
Sora					1								1
					.006								.0003
Mourning dove	4	17	2	4									27
	.012	.025	.013	.009									.0092
Yellow-billed cuckoo		1		1									2
		.001		.002									.0007
Eastern screech owl		7		2	3	5	2	2			1	1	23
		.010		.004	.017	.020	.009	.031			.006	.011	.0078
Long-eared owl		1											1
		.001											.0003
Northern flicker		12	3	5								1	21
		.018	.019	.011								.011	.0071
Red-headed woodpecker	4	63	12	34	1	1							115
	.012	.093	.075	.075	.006	.004							.0390
Hoyt's horned lark										1			1
										.012			.0003
Prairie horned lark		1											1
		.001											.0003
Barn swallow			1	1									2
			.002	.002									.0007
Black-capped chickadee		1											1
		.001											.0003

Name	1936								1937				
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
		1											1

Name	1936 May	June	July	August	Sept.	Oct.	Nov.	Dec.	1937 Jan.	Feb.	Mar.	Apr.	Total
Prairie horned lark			1	1									2
			.002	.002									.0007
Barn swallow		1											1
		.001											.0003
Black-capped chickadee													
Western house wren		1											1
		.001											.0003
Catbird		1											1
		.001											.0003
Brown thrasher		9		2									11
		.013		.004									.0037
Eastern robin	2	10	1	2		1					1		17
	.006	.015	.002	.004		.006					.006		.0058
Eastern bluebird					1								1
					.006								.0003
Migrant shrike		2											2
		.003											.0007
English sparrow	22	180	34	123	45	20	2		3		1	2	432
	.068	.265	.213	.273	.256	.079	.009		.012		.006	.023	.1467
Eastern meadowlark	1	3		1		1							6
	.003	.004		.002		.004							.0020
Western meadowlark	3	11	3	1	3	2							23
	.009	.016	.019	.002	.017	.008							.0078
Eastern red-winged blackbird			1	1									2
			.002	.002									.0007
Baltimore oriole		1											1
		.001											.0003
Bronzed grackle		53	5	10		3						4	75
		.078	.031	.022		.012						.046	.0255
Dickcissel		1											1
		.001											.0003
Lapland longspur									2	1			3
									.008	.012			.0010
Snow bunting										1			1
										.012			.0003

1 Numbers in upper row of line represent the number of casualties; numbers in lower row, the casualties per mile.

English sparrow, *Passer domesticus domesticus* (Linnaeus).
Distribution by county: Adair, 2; Boone, 12; Bremer, 13; Butler, 9; Cass, 7; Clay, 20; Clayton, 26; Dallas, 6; Delaware, 3; Dickinson, 12; Fayette, 15; Floyd, 3; Franklin, 11; Greene, 1; Guthrie, 9; Hamilton, 2; Hancock, 3; Hardin, 7; Harrison, 1; Kossuth, 4; Linn, 5; Mahaska, 5; O'Brien, 2; Palo Alto, 9; Polk, 41; Pottawattamie, 8; Story, 154; Warren, 8; Webster, 2; Winnebago, 2; Winneshiek, 15; Wright, 5.

More casualties were recorded for the English sparrow than for any other species Of 45 birds examined in June, 25 were young.

Eastern meadowlark, *Sturnella magna magna* (Linnaeus).
Distribution by county: Butler, 1; Hamilton, 3; Story, 2.

Western meadowlark, *Sturnella neglecta* Audubon.

Distribution by county: Boone, 1; Dickinson, 3; Fayette, 1; Hamilton, 5; Hancock, 1; Kossuth, 1; Palo Alto, 1; Polk, 1; Story, 9.

The records offered some indication of the distribution and comparative population of this species and its closely related eastern form. In Story County, an area within the broad margin of intergradation for these two birds, nine records were for *neglecta* and two for *magna*.

Eastern red-winged blackbird, *Agelaius phoeniceus phoeniceus*.
Distribution by county: Delaware, 1; Story, 1.
Both records were made where marshes or potholes intersected the highway.

Baltimore oriole, *Icterus galbula* (Linnaeus).
Distribution by county: Cass, 1.

This record was made at a point where the highway crossed a "fill" that caused the roadway to be level with the tree tops.

Bronzed grackle, *Quiscalus quiscula aeneus* Ridgway.

Distribution by county: Boone, 12; Butler, 1; Cass, 1; Clay, 12; Dallas, 2; Delaware, 1; Dickinson, 1; Fayette, 6; Franklin, 2; Hamilton, 3; Hancock, 3; Hardin, 1; Harrison, 2; Kossuth, 1; Linn, 11; O'Brien, 5; Palo Alto, 4; Polk, 3; Story, 10; Warren, 1; Wright, 3.

Thirty-three records of young birds were made, all during June. Nearly all were found near farm groves and windbreaks.

Dickcissel, *Spiza americana* (Gmelin).
Distribution by county: Hamilton, 1.
A higher rate of mortality would be expected for this common "fence-row" species.

Lapland langspur, *Calcarius lapponicus lapponicus* (Linnaeus).
Distribution by county: Montgomery, 2; Story, 1.

Snow bunting, *Plectrophenax nivalis nivalis* (Linnaeus).
Distribution by county: Hamilton, 1.

Mammals

Virginia opossum, *Didelphis virginiana virginiana* Kerr.

Distribution by county: Clayton, 1; Polk, 1; Story, 3.

The opossum population was not normal during the period of these observations, as the severe winter of 1935-36 did much to decrease the numbers, of this species, especially in the northern counties. All the opossums were found near wooded streams or gullies. They were in the gray phase of pelage, and all were adults except one half-grown animal.

Mole, *Scalopus aquaticus* sbsp.
Distribution by county: Dallas, 1; Polk, 1; Story, 1.
These records provided some evidence of the surface actively of this fossorial form.

Mink, *Mustela vison* sbsp.
Distribution by county: Story, 1.
This animal was found 250 yards from water.

Prairie spotted skunk, *Spilogale interrupta* (Rafinesque).
Distribution by county: Boone, 1; Butler, 1; Clay, 2; Floyd, 2; Franklin, 1; Harrison, 1; Madison, 1; Polk, 1; Story, 1; Wright, 1.

Striped skunk, *Mephitis* sp.
Distribution by county: Boone, 1; Butler, 2; Clay, 2; Fayette, 1; Hamilton, 1; Polk, 1; Story, 5; Wright, 2.

Southern woodchuck, *Marmota monax monax* (Linnaeus).
Distribution by county: Dallas, 1.

Thirteen-striped ground squirrel, *Citellus tridecemlineatus tridecemlineatus* (Mitchill).
Distribution by county: Boone, 4; Bremer, 7; Butler, 13; Cerro Gordo, 2; Clay, 3; Clayton, 5; Delaware, 1; Dickinson, 6; Fayette, 6; Franklin, 15; Greene, 2; Hamilton, 6; Hardin, 4; Harrison, 1; Kossuth, 6; Linn, 2; O'Brien, 1; Palo Alto, 5; Polk, 3; Story, 27; Winneshiek, 4; Wright, 4.
The earliest and the latest records for this species were April 18 and October 25.

Franklin ground squirrel, *Citellus franklini* (Sabine)
Distribution by county: Carroll, 1; Cerro Gordo, 1; Clay, 2; Floyd, 2; Greene, 1; Linn, 1; Story, 3.

The casualty rate reflected greatest activity of this species in May, whereas the height of activity for the striped ground squirrel was in August.

Western fox squirrel, *Sciurus niger rufiventer* (Geoffroy).
Distribution by county: Boone, 8; Clayton, 1; Fayette, 1; Franklin, 1; Hancock, 1; Hamilton, 2; Mahaska, 1; Palo Alto, 1; Polk, 1; Story, 6; Warren, 2.

Shaw pocket gopher, *Geomys bursarius* (Shaw).
Distribution by county: Story, 1.
The record provides evidence of the surface activities of this fossorial species.

Baird white-footed mouse, *Peromyscus maniculatus bairdii* (Hoy and Kennicott).
Distribution by county: Hamilton, 3.

Meadow mouse, *Microtus* sp.
Distribution by county: Hamilton, 1.

Muskrat, *Ondatra zibethica* sbsp.
Distribution by county: Boone, 2; Butler, 1; Clay, 1; Fayette, 1; Hamilton, 3; Hardin, 1; Polk, 1; Story, 4.

All except two were recorded within 50 yards of water. One was 300 yards from a drainage ditch and the other about 2 miles from water. Late in August and early in September three casualties were recorded in the vicinity of Little Wall Lake, Hamilton County. At that time there was practically no water in this marsh lake.

Norway rat, *Rattus norvegicus* (Erxleben).
Distribution by county: Boone, 1; Story, 3; Wright, 1.
All were recorded near farm buildings.

White-tailed jack rabbit, *Lepus townsendii campanius* (Hollister).
Distribution by county: Boone, 2; Cass, 1; Clay, 1; Hamilton, 6; Hancock, 1; Hardin, 1; Kossuth, 1; Palo Alto, 2; Polk, 2; Story, 5; Webster, 5; Wright, 8.

TABLE 5.—Mammal casualties.

Name	1936								1937				
	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Opossum	1	1		1		2							5
	.003	.001		.002		.008							.0017
Mole	1	2											3
	.003	.003											.0010
Mink				1									1
				.002									.0003
Spotted skunk	3	3	1	2		1					1	1	12
	.009	.004	.002	.004		.004					.006	.011	.0041
Striped skunk		4		3	3	4						1	15
		.006		.007	.017	.016						.011	.0051
Woodchuck		1											1
		.001											.0003
Thirteen-striped ground squirrel	6	33	8	63	7	5						5	127
	.019	.048	.050	.140	.039	.020						.057	.0431
Franklin ground squirrel	6	3	1	1									11
	.019	.004	.006	.002									.0037
Fox squirrel	2	5	3	5	4	3					1	2	25
	.006	.007	.019	.011	.023	.012					.006	.023	.0085
Gopher			1										1
			.002										.0003
White-footed mouse										3			3
										.036			.0010
Meadow mouse				1									1
				.002									.0003
Muskrat		4	1	6	3								14
		.006	.002	.013	.017								.0048
Norway rat						4		1				1	6
						.016		.016				.011	.0020
Jack rabbit		6		2	3	14	4	1	2	1	2		35
		.009		.004	.017	.055	.018	.016	.008	.012	.010		.0119
Cottontail	11	17	6	8	2	15	8	5	3	4	6	5	90
	.034	.025	.038	.018	.011	.059	.036	.079	.012	.047	.031	.057	.0305

The rate indicated that this species is most active along highways during the fall and winter months.

Mearns cottontail, *Sylvilagus floridanus mearnsii* (Allen).

Distribution by county: Boone, 7; Butler, 2; Carroll, 1; Cerro Gordo, 1; Clay, 3; Delaware, 1; Dickinson, 3; Fayette, 2; Franklin, 2; Greene, 1; Hamilton, 11; Hancock, 2; Hardin, 3; Harrison, 3; Kossuth, 2; Linn, 1; Mahaska, 3; Marshall, 1; Palo Alto, 3; Polk, 5; Pottawatamie, 1; Story, 26; Warren, 1; Winnebago, 1; Winneshiek, 1; Wright, 3.

The rate indicated a rather evenly distributed activity except for the months of August and September, at which time there was a noticeable slump.

REFERENCES

AMERICAN ORNITHOLOGISTS' UNION. 1931—Check-list of North American Birds. Fourth Edition.

GREEN, W. E. AND WATSON E. BEED. 1937—Iowa Quail and Pheasants in Winter. American Wildlife **26**(6):83-84, 90, November.

GUTHRIE, J. E. 1926—The Snakes of Iowa. Agr. Exp. Sta. Bull. **239**, Iowa State College, Ames, Iowa.

MILLER, GERRIT S., JR. 1924—List of North American Recent Mammals, 1923. U. S. Nat. Mus. Bull. **128**.

PRATT, H. E. 1935—Vertebrate Animals of the United States. P. Blakiston's Son and Co., Inc., Philadelphia.

Additional Notes on Birds of Lake Maxinkuckee Region

Samuel E. Perkins III

This series of notes supplements the Evermann and Clark Report of 1920 [1] and my notes of 1927.[2]

Five years ago a beautiful and attractive sanctuary for bird life was established by the Culver Military Academy in its woods. There bird foods adapted to many species and different at different seasons have brought to that concentrated area many more individuals of avian kind than had theretofore been observed in Culver grounds. This baited area itself has done much to foster and increase the birds of this region.

As is natural during every period of ten years a number of wooded areas near the lake in all directions have been lumbered, so that one must look for species which have been ousted in other and neighboring woodlands. However, the important forests named in the previous reports are still intact.

These notes cover the period from 1927 to the end of the year, 1937.

Evermann and Clark reported 175 species of birds. My 1927 notes show 19 additional species. In these notes 21 more are added, making the total species reported for the Lake Maxinkuckee Region, 215.

I am continuing the use of the 1910 American Ornithologists' Union Check List order, adopted by Evermann and Clark, in order more easily to facilitate the use of these notes with previous records.

Colymbus grisegena holboelli Holboell's Grebe. (2.) With two horned grebes I observed for fifteen minutes under 8x glasses an individual of Holboell's grebe on Oct. 30, 1927, at the south end of Lake Maxinkuckee. It is not a common species on this lake as is attested by the scarcity of recorded appearances here.

Colymbus auritus Horned Grebe. (3.) My records of this bird are from the north side of Lake Maxinkuckee when three were seen on Oct. 29, 1926; on the south end of the lake I found two, Oct. 30, 1927; three were close to shore near the big gravel pit on Nov. 26, 1933. Only one spring observation has occurred. It was when I found a specimen on Houghton Pond, April 19, 1935.

Gavia immer immer Common Loon. (7.) I have noted pairs of loons a number of times, but on one occasion, Nov. 6, 1932, it was my good fortune to watch six in close proximity to one another, and one at a distance from them, on Lake Maxinkuckee. This number together on Lake Maxin-

1 Lake Maxinkuckee, Indiana. Dept. Cons. State of Indiana, Pub. 7, vol. 1, (1920).
2 Notes on Birds of Lake Maxinkuckee Region. Proc. Ind. Acad. Sci. 37(1927): 461, 1928.

kuckee is rare. Latest record: Two seen near Perkins' Cottage, July 12, 1937.

Larus argentatus smithsonianus Herring Gull. (51a.) Says Evermann and Clark volume, "The Common American Herring Gull is a spring and fall migrant at this lake." Their dates are all for those seasons. I have recorded it on Lake Maxinkuckee July 4, 1930 (2), Aug. 6, 1930 (3), Oct. 15, 1932 (1), Apr. 1, 1933 (1), Mar. 4, 1935 (4 on ice).

Larus delawarensis Ring-billed Gull. (54.) These gulls, most often when present, perch on ends of long piers on the East side of Lake Maxinkuckee. I have found them in summer as follows: Aug. 21, 1932 (an adult and an immature); July 4th and again on the 5th, 1936, one was near my cottage flying and perching most of both days. One seen on the East side of the lake Oct. 29, 1933.

**Hydroprogne caspia imperator* Caspian Tern. (64.) The beautiful American Caspian tern was apparently not seen at Lake Maxinkuckee or in Marshall County by Evermann and Clark. They make no mention of this rare visitor in this region. Bass Lake in Starke County (next west of Marshall County) was the resting site for three of them along with two herring gulls, Sept. 28 and Oct. 2, 1936. These terns soared over the lake and came back to the same sand bar repeatedly where they stood facing into the wind, on the west side near bush clumps, for several hours during both days. They have a length of 21 inches and a spread of 16 inches and present an unusual sight over an inland body of water.

Sterna hirundo hirundo Common Tern. (70.) Recently I have seen about once each year flocks of as many as 50 of these terns, usually in May, come to Lake Maxinkuckee and remain a day or so. Black terns often accompany them. These species must be commoner than in the days that Evermann and Clark made observations at this lake.

Lophodytes cucullatus Hooded Merganser. (131.) Four male hooded mergansers, and even more females, were observed with other duck species on Lost Lake, Nov. 7, 1937.

Nettion carolinense Green-winged Teal. (139.) On Oct. 2, 1936 two females of this species were watched by me as they rode the water close to the shore of a rain pool pond, a short distance south of Lake Maxinkuckee in Marshall County. Most of the time they kept their heads under wings and appeared quite fearless and tired out, allowing close approach.

Spatula clypeata Shoveller. (142.) The shoveller duck on Evermann and Clark record is represented by a single female taken in 1906. Today in spring, summer and fall it is possible to count regularly on seeing a few pairs on a pond in Marshall County near Outlet Creek, invisible from nearby roads. I believe they breed in this favorable place. Last seen in 1937 on Nov. 7th.

Aix sponsa Wood Duck. (144.) Only once in the last ten years have I seen the formerly abundant wood duck on Lake Maxinkuckee. On Nov. 15, 1935 a single bird was stalked while feeding in the reeds along the south shore of this lake. There is not now any perifery of Lake Maxinkuckee that is suit-

* Indicates species not included in Evermann and Clark Report or in my notes of 1927.

able for the breeding of this species, so they will become rarer here as time goes on.

Glaucionetta clangula americana American Golden-eye. (151.) On Oct. 29, 1933 four males were seen near gravel pit, afloat on the lake. I found a dead and disintegrated specimen of a female of this species on April 24, 1937 on land near the lake edge on the East shore of Lake Maxinkuckee. I saved a wing and foot. The identification was confirmed by Dr. H. C. Oberholser of the Biological Survey.

**Chen hyperborea hyperborea* Lesser Snow Goose. (169.) On November 6, 1932, with three other persons, I stalked in a motor boat a flock of 15 lesser snow geese among larger numbers of lesser scaups and coots. One of the flock was an adult in pure white with black primaries. The other 14 were birds of the year in even gray coloration. We "put them up" several times to be sure of identification. Dr. Evermann reported the greater snow goose on one occasion but as there were no other geese by which we could make comparison and as the lesser snow goose is the Mississippi Valley form, I concluded those seen by me to be lesser snow geese.

Ardea herodias herodias Great Blue Heron. (194.) A heronry of more than 25 nests of this species was located in 1932 four miles west of the lake a little south of Road 10 and in a tamarack swamp full of poison sumac (Rhus vernix). A resident landowner, facing the swamp a quarter of a mile from its north edge, says the colony of herons was first noted two years before. He says it could not have been there before then because he could hear young birds a quarter of a mile away at his home.

In 1935 a blind was erected in this tamarack swamp from which, in succeeding years, photographs were taken of various phases of the nesting history of the herons, and five fledglings were banded. In one of the old nests a pair of great horned owls nested in 1935 and 1937 and raised two young, each of these years.

Five fledglings, only about a week old, were brought from the above heronry, along with their nest, to the Culver Bird Sanctuary by Sergeant Rich of the Academy, in the spring of 1932. They were fed by hand for a time. All were reared and spent the summer in a corral with an artificial pond in same. Later they were wing-clipped. Two that escaped were run down in long grass by me, banded and returned to the corral. The one banded Aug. 28th was captured and released alive at Plymouth, Sept. 2nd, and the other, banded Aug. 21st, was found dead in Culver, Sept. 18th, (1932).

Five other fledglings in the same heronry were banded in the summer of 1935. None of these has become a return.

One pair of great blue herons was seen July 8, 1934 nesting in a tall dead tree in a swamp in Marshall County, near Road 10, east of Culver about three miles. The lone nest and birds were visible from that road when several two-thirds grown young and the parents were at the nest. They were again seen on July 27th, when the birds were perched near their nest.

**Casmerodius albus egretta* American Egret. (196.) Two specimens of American egret were seen along Outlet Creek, just below Lost Lake, Aug. 22 and 25, 1937. With them were ten immature little blue herons. Many of both species were photographed on the above dates and on Aug. 30, 1937. This species was not mentioned by Evermann and Clark in their report.

**Egretta thula thula* Snowy Egret. (197.) Two pure white plumaged snowy egrets, with yellow feet and dark green legs plainly visible, were pursued on Bass Lake, Aug. 18, 1934 and one of them was collected in the water that day. This species is rare in northern Indiana. This specimen is the first for the region. It is in the Amos W. Butler collection now housed at Purdue University.

**Florida caerulea caerulea* Little Blue Heron. (200.) Only noted three places in Lake Maxinkuckee Region by me. At Bass Lake two were seen with several snowy egrets on Aug. 18, 1934. One of these was collected and placed in the Amos W. Butler collection. Three were observed south of Leiter's Ford at a permanent pond in the fall of 1935. On August 22, 1937 upon Outlet Creek edges, a short distance from Lake Maxinkuckee in Marshall County, eleven were observed by me and a group of students where the birds remained in company with two American egrets for more than a week. These were all immatures. Evermann and Clark make no mention of this species.

Gallinula chloropus cachinnans Florida Gallinule, (219.) One of these was reported seen west of Lake Maxinkuckee by Lieut. Evans of the Culver Military Staff, in July, 1929.

**Steganopus tricolor* Wilson's Phalarope. (224.) The entire afternoon of Oct. 8, 1937 I saw a Wilson's phalarope, female, at a farm pond west of and near Outlet Creek. Though there were pintails and shovellers and pied-billeds and least sandpipers on the pond, this bird kept to itself at all times.

**Micropalama himantopus* Stilt Sandpiper. (233.) At a small pond south of Lake Maxinkuckee in Marshall County, near the Fulton County line, I collected a specimen of stilt sandpiper on Sept. 10, 1933. It is not only rare in this county but in the whole state. It was wading along the muddy edges of the pond with pectoral, solitary and spotted sandpipers. The bird was preserved as a study skin and is in the Amos W. Butler collection.

**Pisobia melanotos* Pectoral Sandpiper. (239.) I note that the pectoral sandpiper, which is now a common migrant, must have been infrequent before 1930, as there are no records till later in this region. Evermann and Clark did not record it. My records at this lake are: One noted April 14, 1935; four observed one half mile south of Maxinkuckee, April 26, 1934; eight seen on Culver Military Academy Parade Ground, July 21, 1931; twenty wading near Rochester in Fulton County, Aug. 3, 1934. This wader was observed with snipe and killdeer and spotted sandpipers on Sept. 17 and Oct. 15, 1932, at a rain-filled field pool near Rochester.

**Pisobia minutilla* Least Sandpiper. (242.) On July 25 and 26, 1931 there were five of these little sandpipers in a group searching the seaweed along the east shore of the lake at the mouth of Spangler Creek.

**Crocethia alba* Sanderling. (248.) I collected one at Bass Lake on Sept. 1, 1934. Another was observed at the same lake in Oct., 1936.

**Totanus flavipes* Lesser Yellow-legs. (255.) While this species is quite common at Bass Lake, as its littoral areas are many, few are to be seen near Lake Maxinkuckee. I collected one at a rain pond near a red barn south of Lake Maxinkuckee, Sept. 10, 1933. Same is now in the Amos W. Butler collection, preserved as a study skin. On April 26, 1934 a great flock spread out for feeding at many pools in this county. Many seen at other pools south of this lake in Marshall County, Sept. 4, 1937.

**Bartramia longicauda* Upland Plover. (261.) I saw two at the road edge on fence posts near the Marshall County line along Road 10 in Starke County, on May 22, 1935.

**Charadrius semipalmatus* Semipalmated Plover. (274.) Along Road 10, near the Marshall County Starke County line, I observed on Sept. 3, 1928 a semipalmated plover wading in a field pool with some killdeer. It was easy to differentiate it from its companions. One was observed at Bass Lake in Starke County on Sept. 3, 1934. Five were seen at Bass Lake on Sept. 27, 1936. Two were feeding near the same place on Sept. 28, 1836.

Tympanuchus cupido americanus Greater Prairie Chicken. (305.) I flushed 12 prairie chickens on July 29, 1934 on the dense south edge of a tamarack swamp in Starke County, four miles west of the Marshall County line. On April 23, 1936 I saw a single bird near the middle of the same swamp.

**Phasianus colchicus torquatus* Ring-necked Pheasant. (309.1.) This ring-necked pheasant was introduced into the County of Marshall a few years ago, through the State Conservation Department. I find it infrequently seen there although many were released. On Oct. 8, 1937 one male walked about fearlessly at close range in the Culver Sanctuary observation area. It should not be confused with the ruffed grouse often now and for a century last past wrongly called "pheasant" by hunters and agriculturalists.

Circus hudsonius Marsh Hawk. (331.) Two young which took to the air from the nest located in Overmyers's wet marsh south of the lake were approached on July 25, 1931. There remained one egg in the nest. All of this family circled about for some minutes then disappeared. Though individuals are seen in the lake region yearly this is the only nest found. No nest of the marsh hawk was reported found by Evermann and Clark.

**Buteo lagopus s. johannis* American Rough-legged Hawk. (347a.) This hawk is increasing in numbers in this area. On March 4, 1935 and again on March 10, 1937 specimens of this feather-legged hawk were seen in Fulton County, but not previously in Marshall County. Since then two were seen in the air at the same time banking, flying low and slowly sailing over Houghton Pond north of Road 10, near the west line of Marshall County, on Nov. 7, 1937. Evermann and Clark record no report of this hawk.

**Tyto alba pratincola* Barn Owl. (365.) One of this species was killed by Archibald Kirshbaum at his barn north of Culver in August, 1934. When brought to the Culver *Citizen* office it was found too decayed to mount.

Strix varia varia Barred Owl. (368.) On May 8, 1936 we observed two half grown young perched together high in an elm near the west bird-observation house in Culver Bird Sanctuary.

Otus asio naevius Screech Owl. (373m.) Two white-plumaged immatures, lately out of nest which was in a tree near my cottage on the East Side of Lake Maxinkuckee, were flying and perching low for several hours on each of the following days: May 30 and 31, 1937. A gray-phase adult called them to the different trees it flew into.

Bubo virginianus virginianus Great Horned Owl. (375.) A fine specimen is mounted and can be seen in the Culver *Citizen* office in Culver, that was killed in Marshall County in June or July, 1927. The bird had a wing-spread of 54 inches. One seen by me June 22, 1931 in Vonnegut's Woods. Another of these "cat-owls" was shot and killed while clutching a large rooster in its talons, Sept. 21, 1932 by Clarence Kline. This specimen was mounted and is at Ewald's market in Culver, Indiana. For two seasons a pair of great horned owls have nested in a blue heron's nest in a heronry in Starke County, near Culver (see Great Blue Heron herein). Each brood was raised with success. Neither adults nor fledglings were antagonistic to the herons.

Nyctea nyctea Snowy Owl. (376.) A mounted specimen that was killed in 1931 in Marshall County, can be seen in the Culver *Citizen* office at Culver.

Antrostomus vociferus vociferus Whip-poor-will. (417.) In my experience this form is still uncommon near the lake. One was heard July 2, 1930, in the evening, on the Academy grounds. On Sept. 11, 1932, I picked one up in the gravel roadway south of the lake, that had been run over and killed. These are my only recordings of it during the last ten years. On June 26, 1933, I consulted an old resident who informed me that twenty-five years ago this species was quite common in summer.

Sayornis phoebe Phoebe. (456.) An adult, breeding on the east shore of Lake Maxinkuckee, was banded No. 469017 on July 2, 1927. It came back to the same yard, nested and raised young, was trapped again on July 5, 1935 and found, on reading the band, to be the same bird. It was then mated with No. 34-160651, a different mate. It was an unusual record of avian fecundity; a bird whose breeding life was known to be through nine consecutive years.

**Empidonax flaviventris* Yellow-bellied Flycatcher. (463.) On Aug. 14, 1933, while in the tamarack swamp where a heronry is located in eastern Starke County, Sidney R. Esten, William Baker of Maryland and myself watched, under glasses, an individual of this flycatcher. Evermann and Clark do not report the species seen in the Lake Maxinkuckee region.

Otocoris alpestris praticola Prairie Horned Lark. (474b.) On July 5, 1937 an adult prairie horned lark was flushed with two three-fourths grown young, near Houghton Pond in Marshall County. This is the first nesting record of the species in this county that has come to my attention.

**Sturnus vulgaris vulgaris* Starling. (493.) This European species began

to appear in this region in 1929 when Capt. Hulsburg collected two on August 10th. In August, 1930 three were seen on the golf course as I passed there. Forty in two flocks of about twenty each were watched just south of Norris Inlet swamp, on July 22, 1931 and three were noted (one an immature) in Vonnegut's "Hollyhocks" the same summer. In 1932 one flock of more than 1000 birds circled and wheeled and perched in Norris Inlet on June 30th, where I caught a young bird and banded it. They are now seen daily about the lake. They have bred annually since 1933 in pigeon boxes in Vonnegut's barn along the East Side road.

**Xanthocephalus xanthocephalus* Yellow-headed Blackbird. (497.) On May 8, 1937, with a companion I sighted a male yellow-headed blackbird on a fence post near the road south of the lake. We saw it with 8x glasses and noted all marks of the bird familiar to us from study in the Calumet Region in northern Indiana, where the species is numerous and breeds.

Icterus galbula Baltimore Oriole. (507.) On June 22, 1931, there were two nests of the Baltimore oriole only fifty feet apart occupied at the same time at Crescent Beach, the Perkins' cottage on East Side road, facing Lake Maxinkuckee.

Chondestes grammacus grammacus Lark Sparrow. (552.) Seen July 4, 1928 at lake edge near the gravel pit. On July 20, 1929 it was watched for several minutes at Vonnegut's; again July 31, 1929 at the same place.

Zonotrichia albicollis White-throated Sparrow. (558.) Evermann and Clark's earliest fall record of this bird is Oct. 4 (1913). There was one in the Culver Sanctuary, Sept. 18, 1932. They were common by Oct. 2, 1932.

Spizella passerina passerina Chipping Sparrow. (560.) One of the birds of this species banded in Vonnegut's Orchards, was killed at Buccatunna, Mississippi, Dec. 25, 1930, three and one half years later.

Passerina cyanea Indigo Bunting. (598.) I have located nests near the lake as follows: July 3, 1931, 3 young hatched; July 10, 1931, nest with 3 eggs and one cowbird egg.

Spiza americana Dickcissel. (604.) I am able to report nesting records of this species for the Lake Maxinkuckee Region. It was as I drove west on the county line road between Marshall and Fulton Counties about five miles east of the lake, on Aug. 6, 1930 the feeding bird led me to its nest in the roadside sprouts where four fledglings crouched. I photographed and banded them. July 11, 1932 a pair was feeding young near their nest in Overmyer's marsh. The species was unusually numerous in the summer of 1937.

Progne subis subis Purple Martin. (611.) Since I wrote last on the birds of this region bird houses have been erected at Vonnegut's and other yards on the east side of the lake. These boxes with many rooms have attracted martins and now they are almost as numerous as on the west shore. Several Indianapolis banders and myself banded fledglings in May and June in recent years. One box along the road on Vonnegut's farm contained both English

sparrows and martins nesting in different apartments at the same time. Martins are now among the commonest nesters about the lake. On every side colony houses have been erected to encourage them. Culver Military Academy grounds have a dozen or more large boxes on tall poles which are occupied almost to capacity annually. While many hundreds have been banded no distant returns have been reported. One bird came back here a succeeding year after it was banded and unfortunately was shot by a boy in Culver.

Petrochelidon albifrons albifrons Cliff Swallow. (612.) By a typographical error in my "Notes on Birds of Lake Maxinkuckee Region." published in Proc. Ind. Acad. Sci., vol. 37, 1927, the word sparrow appears instead of swallow on p. 464.

Bombycilla cedrorum Cedar Waxwing. (619.) Evermann and Clark do not record the finding of the nest of this species. Four young several days out of the nest were being fed on July 20, 1931 in the middle of a sassafras tree along the road south of Overmyers'. The adults brought berries of some kind from bushes almost as far away as the lake edge, which were given the young in turn. A pair nested near the tents of woodcrafters in mid-summer, 1936, as reported at Culver Council Fire.

Vireo gilvus gilvus Warbling Vireo. (627.) Nest and eggs were observed at Crescent Beach, Lake Maxinkuckee, June 22, 1931. Nest with two fledglings was observed at Busart's, one eighth of a mile west of the lake, June 28, 1933. The fledglings were banded by me. In a maple tree on the East Side road, a pair was nesting June 19, 1933. I watched a male and female change places many times while incubation was in progress the week of May 3-10, 1937, in an elm tree in my yard facing the East Side road. With this species the male sings in the nest tree often very close to the nest and frequently while brooding upon the eggs. The song is very like one set of strains from a well known opera.

**Vermivora pinus* Blue-winged Warbler. (641.) Both parents were observed in the act of feeding a young bird of this species about a week out of the nest. This was northeast of the lake a quarter of a mile, on July 15, 1929. We used field glasses in watching the family.

Dendroica cerulea Cerulean Warbler. (658.) This species seems to continue rare. In the past five years I have only seen it once. On June 19, 1929 a male was observed at close range on the north side of Vonnegut's Orchard.

**Oporornis philadelphia* Mourning Warbler. (679.) On May 19, 1935, as I made observations in the Culver School Sanctuary I saw a mourning warbler male in the trees at its edge.

Icteria virens virens Yellow-breasted Chat. (683.) In the summer of 1928 two males were seen in the cut-over woods where poke berries and papaws grew in clumps, one-eighth of a mile northeast of Vonnegut's "Hollyhocks." At the same time on June 19, 1929, two males were stalked. Watching every few days thereafter I located a nest with three eggs therein on July 4th. The female was brooding. On July 20th the fledglings were about ready to leave

the nest so I banded two of them. This appears to be a late date for breeding of this species and the first record of the nesting of the chat in the Maxinkuckee Region in northern Indiana, but not as unusual as the nesting record from Ohio reported as Sept. 8 (1935). (See Bird Banding magazine, Jan. 1936, p. 46.)

Anthus spinoletta rubescens Pipit. (697.) Records by Evermann and Clark of this species are all of birds migrating south. A group of us on May 7, 1934 came upon twenty or more near King's pond in Fulton County, on north migration.

Mimus polyglottos polyglottos Mockingbird. (703.) Sometimes one, at other times two of these fine birds were seen by me along the Fulton-Marshall County road in Marshall County, about six miles east of Lake Maxinkuckee, quite regularly in summer. My dates are May 12 and 13, 1933 (On this date I was accompanied by Dr. and Mrs. Amos W. Butler. We noted it several times during each of these days). I am sure this pair nests but have not been able to produce the evidence. It was seen again at the same place the following year; Aug. 10, 1929; June 23, 1931; July 21, 1936. On July 5, 1935 I observed a pair feeding young a few days out of the nest situate in a rose bush at Ed. Hiatt's home on State Road 17, about three miles south of Kewanna in Fulton County.

Toxostoma rufum Brown Thrasher. (705.) This bird is on the increase hereabouts. In 1932 I found five adults at a time on July 10, one on July 11, one on July 13, and five on July 24. It was more common than the catbird in the summer of 1932. On June 29, 1933 I found a nest and two eggs in Culver Bird Sanctuary. One was observed as late as Oct. 15 (1935) scratching among the leaves near my cottage. On Sept. 4, 1936 I saw my first bird of the year in Culver Bird Sanctuary. The species was scarcer this year (1937). Three were observed May 30, 1937.

Thryothorus ludovicianus ludovicianus Carolina Wren. (718.) On Sept. 3, 1928 I stalked another of these birds rare in the Maxinkuckee Region.

Troglodytes aedon aedon House Wren. (721.) This species continues to thrive and increase but not at the expense of other species as in many localities. There were many young towhees, cardinals, robins and titmice seen in areas where wrens bred in numbers. Though many have been banded, both adults and fledglings, no distant recovery has been had, as yet. Almost every cottage yard on the east side of the lake had two pairs of house wrens nesting there. I found 8 nesting pairs in June and July in 1936 in four yards, Vonnegut's, Andrew's Marmon's and my own, as examples. The rural mailman covering that territory reports about 20 out of 60 rural mail boxes were used by wrens that season. The species seems as numerous this year (1937).

Baeolophus bicolor Tufted Titmouse. (731.) Since a greater interest in attracting birds to home gardens prevails this attractive and lively "peter bird" is regularly found in the yards bordering the lake—a different situation from the experience of Evermann and Clark.

A Study of the Radulae of Snails of the Family Pleuroceridae*

Samuel Wilbur Howe

I. Introduction

In an earlier paper the writer (Howe, 1930) gave an analysis of the variability of the median tooth of the radula of *Goniobasis livescens* in an attempt at a critical evaluation of the validity of the use of radular characters in taxonomy. More recently the writer has extended the study to include representatives of five other members of the family Pleuroceridae. In the course of this study more than 150 radulae have been studied critically and subjected to an analysis of size relations of the teeth and variability in radulae formula. With these detailed observations as background, extension of the previously published conclusions have been made to cover other members of the Pleuroceridae. Space does not permit of publication of all the original observations in full detail. The present paper represents a summary of the study.

II. Materials and Methods

This study has been extended to cover other species of the family Pleuroceridae. *Pleurocera acuta, Pleurocera canaliculatum, Pleurocera lewisii, Goniobasis livenscens, Angitrema armigera,* and *Angitrema verrucosa* were the species used in the present investigation. The specimens of *Pleurocera acuta* were collected frfom the Sangaman River above Mahomet, Illinois in May 1931; the specimens of *P. lewisii* were collected from the Illinois River above Peoria, Illinois, in May, 1931 and from Lake Senachwein in June, 1935; the specimens of *P. canaliculatum, A. armigera,* and *A. verrucosa* were collected from the Ohio River near Joppa, Illinois in August, 1933; and the specimens of *G. livescens* were collected from the Rocky Ford River near Hillsboro, Ohio.

The methods used in this study were the same as those used by the writer in previous studies (Howe, 1930).

III. Statement of Problem

Continuing the problem as outlined in a previous paper (Howe 1930), the writer has treated the following aspects of the problem of analyzing the reliability of radular characters in the taxonomy of gastropods.

1. An accurate determination of variability in size of median teeth in the same radula, whether graded variation from one end to the other, chaotic, or definitely correlated with worn, functional, and newly developing regions of the radula.

* Contributions from the Zoological Laboratory of the University of Illinois, No. 521.

2. An examination of the influence of age upon the relative width of the median teeth as encountered in snails of different sizes.

3. Relative widths and lengths of the central cusps on the median teeth of radula of snails of different sizes with special reference to change in size of central cusp with change in size of median teeth.

4. A determination of the variability in the number and arrangement of cusps on the various teeth in the same animal and in different animals, whether correlated with definite shell characters or uncorrelated.

IV. Observations on Radulae

Pleurocera acuta

Variations of median tooth. Goodrich (1936) finds variation in the radulae of Pleuroceridae which "may involve the individual mollusk, the colony to which it belongs, or all its race." He also indicated that variations in number of cusps on median teeth were as a rule not variable within a colony but were outside colonies. His observations were that the laterals showed less variations than the other radular teeth in Goniobasis. Van Cleave and Richey (1936) found variations in the size of radular teeth of five species.

A. In the same radula. Three entire radulae of *P. acuta* were examined to determine the variation in size of median teeth in the same radula and the relation of this variation to position in the radula. In all of the radulae examined, the teeth of the worn region were largest (70μ to 100μ) and those of the undeveloped region the smallest (60μ to 92μ), with those of the functional region between these in size (64μ to 92μ). A variation as much as 24μ (64μ to 88μ) was found in the same radula. Some of the other radulae examined showed but two of the three regions in such condition that they could be examined, the other portion being either twisted into an unintelligible mass or the teeth broken by the pressure applied to isolate the teeth. These showed the functional teeth wider than the undeveloped teeth in every case. Thus we have evidence of progressive increase in width of median teeth from the undeveloped region to the worn region of the radula of *P. acuta*. In other radulae examined, variation as much as 10μ (54μ to 64μ) were found. Due to the process used to isolate the teeth, the position of these teeth in the radulae could not be determined. From the observation obtained in the examination of the three entire radulae, it seems probable that the size differences depend upon position in the radula and are not chaotic.

B. In different radulae. Thirty-six specimens of *P. acuta* varying from 9.9 mm. to 25.0 mm. in length of shell were examined for variations in size of median teeth of the radulae from different animals. Tooth size varies directly with shell size. Variation in the width of the median tooth from 44μ in the smallest specimen to 84μ in the largest specimen were found. Some digression from a progressive increase in the width of the median tooth with increase in shell size was present. This may be explained by the variations within the individual radula mentioned above. There is a definite uniform increase in the size of the individual teeth of radulae from different individuals progressing

with increase in size of the shell. This does not show so well from looking at the smallest or largest tooth from one radula and comparing it with the smallest or largest tooth from another radula. It is shown, however, from the overlapping in the sizes of teeth in the different radulae. In the radulae from all shells more than 22.2 mm. in length, all median teeth are wider than 70μ. If the width of each tooth in each radula were compared with the width of each tooth in every other radula, the correlation of increase in width of median teeth with increase in size of shell would probably appear still closer. Also the diameter of the shell must be considered in shell size as well as length of the shell.

The differences in width of individual teeth from different radulae were as great for snails of large size as for those of small size. There was a range from 44μ to 70μ in shells from 9.9 mm. in length to 15.0 mm. in length and a range from 66μ to 100μ in radulae from shells from 15.7 mm. in length to 25.0 mm. in length.

C. In width of central cusps. Observations were made on four entire radulae. In two of these, the central cusps of the median teeth were widest in the worn region (12μ to 16μ) and narrowest in the undeveloped region (8μ to 14μ) with those of the functional region intermediate. In one of the radulae, the central cusps of the functional and worn median teeth were the same width, 12μ. The central cusps of the functional and undeveloped teeth were of the same width in one radula (14μ). Examination of radulae in which the central cusps of only two regions could be measured showed the central cusps of the undeveloped teeth narrower than the central cusps of the functional teeth in most cases. There was one radula in which the width of the central cusps of the functional teeth was the same as the width of the undeveloped teeth.

The widths of the central cusps of median teeth and the widths of the isolated median teeth show definite correlation between width of central cusp and width of median tooth. It is very probable that the width of the central cusp varies with the width of the median tooth, and, like it, varies directly with position in the radula. It is probable that a fairly definite ratio exists between the width of its central cusp and the width of the median tooth.

D. Variations in length of central cusps. The lengths of the central cusps of the median teeth from the radula from *P. acuta* vary considerably both in their own radula and in different radulae. There is nothing very definite shown by these variations. The cusps are worn by use and even an apparent correlation with size of median teeth and position in radula would mean nothing, because it might be coincident, due to wear.

Variability in number and arrangement of cusps on the various teeth. There was considerable variation in the number of cusps on the various teeth. There were only ten of the thirty-six specimens examined which showed a radular formula like that cited by Baker (1928) for P. acuta. The other twenty-six specimens showed variations in some or all of the seven teeth in a transverse row. Sixteen specimens showed variations in the number of cusps on the median teeth. Fourteen of these showed variation within the same

radula, while two showed variation from the usual formula but were constant within that radula. Some radulae showed great variation within the radula $\frac{1}{5\text{–}8,\ 1,\ 4\text{–}6}$, while others showed little variation, $\frac{1}{4\text{–}5,\ 1,\ 4\text{–}5}$. Great variations were not found within the radula in very many radulae. Only four radulae of the thirty-six examined showed very great variation within the same radula. Twelve specimens showed variations in the number of cusps on the intermediate tooth from the formula as given by Baker. Ten of these specimens showed variation from the normal formula but constancy within the radula. Seventeen specimens possessed radulae with the second lateral teeth varying in number of cusps. Four of these variations were entirely outside the range of Baker's formula, while the other thirteen varied from the formula but had teeth within the range of the formula. Fifteen specimens were without variation in the number of cusps on the intermediate teeth. In only one specimen was there variation from Baker's formula for the first lateral teeth. Twenty-four of the radulae examined had first lateral teeth with no variation within the radula, while eight specimens showed variation within the radula, but within the range of the formula.

The greatest number of variations (17) in number of cusps were found in the intermediate teeth but the greatest variation was in the second lateral tooth, $\frac{1}{9\text{–}14}$. There was no definite correlation in variation among the various teeth. There was sometimes a distinct variation in one of the teeth with no variation shown in the adjacent teeth. The median tooth showed a variation $\frac{1}{4\text{–}5,\ 1,\ 4\text{–}5}$ while the intermediate and lateral teeth showed no variation, $\frac{1 \quad -1\ -1}{3,\ 1,\ 3 \quad 8 \quad 7}$, all coming within the formula as given by Baker. There seems to be no correlation between the variable shell characters and variation in the number of cusps on the various teeth.

Pleurocera lewisii from Illinois River above Peoria, Illinois

Variability of the median tooth. A. In the same radula. Examination of seven entire radulae of *P. lewisii* yielded the following results. In five radulae, the median teeth of the worn region are widest (58μ to 88μ) and those of the undeveloped region smallest (48μ to 76μ), the median tooth of the functional region being between those two in width (56μ to 88μ). The other two radulae showed the teeth in the worn region (76μ to 80μ) smaller than the teeth in the functional region, (80μ to 82μ). Five other radulae, with the undeveloped and functional regions intact, possessed wider median teeth in the functional region (64μ to 80μ) than in the undeveloped region (52μ to 80μ). This gives clear evidence that the relative width of the median tooth depends directly upon position within the radula. Variations in the width of the median tooth as great as 22μ (from 58μ to 80μ) were observed in the radulae in which the teeth had been isolated. There is no way of determining the original position of these teeth in the radula but it is probable that they were arranged as were those in the seven radulae mentioned above.

B. In different radulae. Thirty-six radulae were observed for variations in the width of the median teeth in different radulae. Variations from 46μ in the smallest specimen to 88μ in the largest specimen were observed. Median teeth of radulae from shells of different sizes can be expected to show variations in width.

C. Variations in width of central cusps. Ten radulae were in such shape that the width of the central cusps from three different regions could be compared. The central cusps of the worn teeth (10μ to 19μ) were widest and the central cusps of the undeveloped teeth (4μ to 10μ) were narrowest in six of these radulae. The central cusps of the functional teeth (7μ to 14μ) were between these two in width in the six radulae. A number of other radulae were in condition to allow comparison of widths of central cusps from two of the three regions of the radula. In every case, these radulae had the central cusps of median teeth in the undeveloped region smaller than the central cusps of teeth of the functional region or the cusps in the worn region wider than cusps in the functional region. The evidence indicates that the width of the central cusp depends on its position in the radula as does that of the median tooth and varies with the median toooth upon which it is borne. There is a definite increase in width of central cusp with increase in size of shell. In one of the ten entire radulae, the cusps of the undeveloped region (4μ to 8μ) were smallest and the cusps of the other two regions were the same size (10μ). Another of the ten radulae showed central cusps largest on the teeth of the worn region (12μ to 14μ) and the same size in the other two regions (10μ to 12μ). The other two radulae possessed median teeth in all three regions with cusps of practically the same size.

D. Variations in length of central cusps. Examination of thirty specimens gives the following results. In all but five cases, the central cusps of the functional regions are longest (10μ to 26μ) while those of the worn regions are shortest (2μ to 18μ) and those of the undeveloped regions (10μ to 20μ) were between these two in length. In five radulae, however, those of the undeveloped region (16μ to 20μ) were longer than those of the functional region (12μ to 18μ). These differences can be explained by the wear upon the functional teeth. It seems that the central cusp grows in length as the tooth develops but as soon as the tooth becomes functional, the cusps are worn shorter. Therefore one would expect to find the shortest cusps in the worn region and a grading series in the undeveloped and functional regions. When the teeth are subjected to considerable wear, those in the functional region will be shorter and, when little wear has occurred, the functional cusps will be longer.

Correlation between width of the median tooth and shell size. Examination was made of thirty-six specimens of *P. lewisii* varying from 9.1 mm. to 31.9 mm. in shell length to determine the range in width of the median tooth in correlation of width of the median tooth with shell size. The width of the median tooth was found to vary from 48μ in specimen 27B which was 11.7 mm. in length of shell, to 92μ in specimen 31B which was 28.9 mm. in length of shell, a difference of 44μ. These two widths represent the least and greatest

widths of median teeth in the radulae examined. This shows progressive increase in width of median tooth with increase in size of shell. Particularly is this true when one directs attention to the overlapping of sizes rather than noticing only the largest and smallest teeth of the various individuals, and comparing them with teeth of radulae from shells of different sizes. While there are some very distinct digressions from this progressive increase in size of mediian tooth with size of shell which can hardly be explained by variation within the radula or diameter of the shell, no explanation is offered for these digressions. It is interesting to note, however, that there are other very striking variations found in this species to be discussed later in this paper. It may be possible that ecological varieties are represented by a few specimens in this investigation.

Variation in number and arrangement of cusps on the various teeth. Of the thirty-six specimens examined during the progress of this investigation, not a single specimen of *P. lewisii* was found to possess a radula with the formula cited by Baker for *P. elevatum lewisii* $\frac{1-1-1-1-1-1-1-1-1}{11\ \ 8\ \ 5,1,1\ \ 3,1,3\ \ 1,1,5\ \ 8\ \ 11}$. The radulae used herein showed a great variation in the number of cusps on the various teeth. The formula which was most often found was $\frac{1-1-1-1-1-1-1-1-1}{8\text{–}9\ \ 6\text{–}7\ \ 3,1,3\ \ 4,1,4\ \ 3,1,3\ \ 6\text{–}7\ \ 8\text{–}9}$. This formula was found in ten radulae. Twenty-four of the thirty-six specimens examined showed deviations from the above formula in the median tooth. Of this number only two are constant within the radula, the others showing range within the radula from $\frac{1}{4\text{–}5,\ 1,\ 5\text{–}4}$ to $\frac{1}{4\text{–}9,\ 1,\ 9\text{–}4}$. Most of these (twelve) varied by at least four in the number of cusps on the median teeth within the same radula. There was not so much difference in the number of cusps on the intermediate teeth; one-half or eighteen of the specimens were consistent with the above formula for the intermediate teeth. Fourteen of the varying radulae showed inconsistency within the radula, leaving four specimens with radulae varying from the formula in the number of cusps on the intermediate teeth but constant within the radula. The second lateral tooth varied in the number of cusps borne from the above formula in thirteen radulae, three of which were entirely outside the range of the above formula. Only seven radulae possessed first lateral teeth with variations from the formula; one of these has one more cusp than shown in the formula and six of them possessed teeth with one less cusp than is indicated by the above formula. The greatest number of variations (24) was found in the median teeth as was also the greatest single variation $\frac{1}{4\text{–}9,\ 1,\ 4\text{–}9}$ from the formula of Goodrich, $\frac{1}{4,\ 1,\ 4}$. No explanation is offered for the variation described above, though ecological factors might be present.

Pleurocera lewisii from Lake Senachwein

Morphology of the radulae. The radulae of *P. lewisii* from Lake Senachwein showed the three regions, worn, functional, and undeveloped. The formula of the radulae of these specimens from Lake Senachwein is the same as

the formula for *P. lewisii* from the Illinois River above Peoria, Illinois.

This material from Lake Senachwein is treated separately because it gives evidence that within a well defined species local colonies may show distinct differences in tendency to vary.

Variability of median teeth. A. In the same radula. Seven radulae were in such condition that measurements could be made of the widths of the median teeth in each of the worn, functional, and undeveloped regions. In each radula, the median teeth of the functional region were widest (84μ to 98μ), the median teeth of the undeveloped region were least wide (68μ to 84μ), while the median teeth in the worn region were intermediate (76μ to 94μ). Two other radulae were in such condition that measurements could be made of the width of median teeth in the functional and undeveloped regions. In both radulae, the teeth of the functional region were wider (76μ to 88μ) than the median teeth of the undeveloped region (62μ to 72μ). Thus the widths of median teeth are definitely shown to vary with position in the radula and are not chaotic variations.

B. Variations in different radulae. Thirty-one radulae of *P. lewisii* from Lake Senachwein were examined to determine the variability in width of median teeth from different radulae. A variation as great as 34μ, from 62μ in specimen 29d with a shell length of 17.3 mm. to 96μ in specimen 11d with a shell length of 31.0 millimeters.

Correlation between the width of median tooth and size of the shell. Examination of measurements of median teeth and shells showed a definite correlation between the widths of median teeth and size of shell from which the snail was taken. Radulae from snails with shells from 17.3 mm. to 19.6 mm. in length possessed median teeth varying in width from 62μ to 80μ while radulae from snails with shells varying in length from 26.6 mm. to 31.0 mm. possessed median teeth varying in width from 76μ to 96μ. Altogether, the correlation between shell size and width of median teeth is not so definite in the specimens of *P. lewisii* from Lake Senachwein as it is in the specimens of *P. lewisii* from the Illinois River above Peoria, Illinois, or in specimens *P. acuta* or *G. livescens*. Some very obvious exceptions are present, notably one specimen with a shell length of 25.9 mm. had median teeth with widths from 96μ to 100μ while another specimen with a larger shell (29.8 mm.) has median teeth with width from 80μ to 84μ. There is no distinct overlapping shown here, the widest tooth in the smaller specimen is not so wide as the smallest median tooth measured in the larger specimen. Variations within the radula are not great enough to account for these differences.

Variations in number and arrangement of cusps of the various teeth. Accurate determinations were made of the radular formula for eleven specimens. Of these, six showed variations in the number of cusps on the median teeth. Five of these varied from the formula but were constant within the radula. One varied both from the formula and within the radula. The number of cusps on the intermediate teeth varied from the formula in only two specimens and in these two were constant within the radula. Only two speci-

mens showed irregularity within the radula in the number of cusps on the second lateral teeth. Only one specimen showed conditions beyond the range of the normal formula in the number of cusps on the second lateral teeth. Three radulae varied within the radula in the number of cusps on the first lateral teeth. This is significantly different from variations in P. lewisii from the Illinois River above Peoria, Illinois, which were both more frequent and the variations within the radula mucch greater. The difference must be due to ecological factors which are different since some of the material came from the Illinois River above Peoria, Illinois and some of it came from Lake Senachwein. It may seem that the specimens from the two different localities represent different ecological variations or tendency to local fixation of variable characters.

Pleurocera canaliculatum

Morphology of the radula. The worn, functional, and underveloped regions were distinct in the radulae of *P. canaliculatum*. The radulae of *P. canaliculatum*. The radulae of *P. canaliculatum* showed considerable variability though the formula most often was $\frac{1-1-1-1-1-1-1-1-1}{6\quad 6\quad 4,1,3\quad 4,1,4\quad 3,1,4\quad 6\quad 8}$.

Variations in the width of median teeth. A. In the same radula. Radulae from two specimens were in such condition that measurements could be made of the median teeth in each of the three regions; worn, functional, and undeveloped. In both of the radulae, the median teeth were widest in the functional region (56μ to 62μ) and narrowest in the undeveloped region (46μ to 54μ) while the teeth in the worn region were intermediate (52μ to 62μ). Five other radulae were in such condition that measurements could be made of the widths of the median teeth only in the functional and undeveloped regions. In every radula, the width of the median teeth in the functional region was greater than in the undeveloped region. The widths of median teeth are then not chaotic within the same radula, bu depend upon the position of the tooth in the radula.

B. In different radulae. Thirty-five radulae from specimens of P. canaliculatum were examined and the median teeth measured to determine the variations in the width of median teeth from snails with shells of different size. Variations as great as 44μ (from 44μ in specimen 29E to 88μ in specimen 5E) were found.

Correlation between width of median tooth and size of shell. The variations in width of median teeth from different radulae were distinctly correlated with the size of the shell from which the snail was taken. This is evident when the overlapping of tooth widths is considered. All radulae from snails with shells from 12.3 mm. in length to 22.8 mm. in length possessed no median teeth so wide as 70μ while all radulae from snails with shells from 24.8 mm. in length to 34.1 mm. in length possessed some teeth with a width of 70μ. The information furnished by examining measurements of widths of median teeth and length of shell of thirty-five specimens shows clearly that variations in width of median tooth are definitely correlated with size of shell. This

is very evident when overlapping of sizes and diameter of shell as well as length of shell are considered.

Variations in number and arrangement of cusps on the various teeth. The number of cusps on the median teeth deviated from the formula in only two of ten radulae examined. These varied by only one cusp but within the radula the number of cusps was not constant. The greatest variation was found in the number of cusps on the intermediate teeth. Six of the ten radulae showed variations in the number of cusps on the intermediate teeth, four of which varied within the radula. Two varied from the formula but were constant within the radula. Variations as great as two in the number of cusps in the intermediate teeth were found on the same radula. Only four radulae showed variations from the formula in the number of cusps on the second lateral teeth. Three of these were constant within the individual radula and one varied within the radula. One specimen showed variation from the formula as much as two in the number of cusps but this number was constant within that radula. Three radulae showed variation in number of cusps on the first lateral teeth outside the range of the formula, two of them also showing variation within the radulae. One other radula showed variation within the radula from the formula as well as having some first lateral teeth with the same number of cusps as is shown in the formula. The greatest variation shown is in specimen 9E $\frac{(\ 1\ )}{(12\text{–}11)}$ as for formula $\frac{(1)}{(8)}$ while the greatest variation within the radula is $\frac{(\ 1\ )}{(9\text{–}11)}$.

Angitrema verrucosa

Morphology of the radula. The radulae of *A. verrucosa* shows the three regions; worn, functional, and undeveloped. The formula for the radula varies. The formula most often found is

$$\frac{1 - 1 - 1 - 1 - 1 - 1 - 1 - 1}{11\text{–}14 \quad 6\text{–}7 \quad 3, 1, 1 \quad 4, 1, 4 \quad 1, 1, 3 \quad 6\text{–}7 \quad 11\text{–}14}.$$

Variation in the width of median teeth. A. In the same radula. In three specimens of *A. verrucosa,* radulae were mounted in such condition that all regions could be measured. In all of the radulae, the median teeth of the functional region (112μ to 132μ) were wider than the median teeth in either the worn region or undeveloped region. In four of the radulae, the median teeth in the worn region (112μ to 126μ) were wider than the median teeth in the undeveloped region (96μ to 116μ) while in one radula the median teeth of the worn region and the undeveloped region were the same width, (120μ). Three radulae were in such condition that measurements could be made of the widths of median teeth in both the functional and undeveloped regions but not in the worn region. In each radula, the median teeth of the functional region were wider (114μ to 124μ) than the median teeth of the undeveloped region, (110μ to 116μ). The variations in the width of median teeth within the individual radulae of *A. verrucosa* are not chaotic. The width of the median tooth depends upon the position of the tooth in the radula.

B. In different radulae. Twenty-seven radulae from specimens of *A. verrucosa* were examined and measurements made of the widths of median teeth to determine the variability in different radulae. Variations as great as 60μ were found. The greatest variation between entire radulae was 36μ. One specimen with a shell length of 16.9 mm. possessed a radula in which the largest measured median tooth was 100μ in width while specimen 1f, with a shell length of 20.4 mm., possessed a radula in which the smallest measured median tooth was 136μ in width.

Correlation of variation in width of median teeth and size of shell. There is a correlation of the variations in width of the median teeth with size of shell. This is more easily seen when overlapping of sizes is considered. All shells from 19.4 mm. to 22.1 mm. in length yielded radulae which possessed teeth 120μ in width. These shells were somewhat decollated, which makes it necessary to give more consideration to the diameter in determining shell size. Overlapping of widths of median teeth should therefore be more obvious than differences in width of teeth as correlated with shell size.

Variation in number and arrangement of cusps on the various teeth. Variations in the number of cusps on the median teeth were found in two of the fourteen radulae of *A. verrucosa* examined. One of these showed variation from the formula but was constant within the radula. In no case was the variation in number of cusps on the median tooth greater than one on each side of the central cusp. Six of the fourteen radulae possessed intermediate teeth varying in number of cusps from the formula. In all radulae, the number of cusps on the intermediate teeth was constant within the radula and in no case was the variation in number of cusps greater than one. In five of the radulae, the number of cusps was smaller $\frac{(\ 1\ )}{(2,\ 1,\ 1)}$ and in one case the number of cusps $\frac{(\ 1\ )}{(4,\ 1,\ 1)}$ was larger than in the usual formula $\frac{(\ 1\ )}{(3,\ 1,\ 1)}$. Very little variation was found in the number of cusps on the second lateral teeth from that shown by the formula. Two radulae showed second lateral teeth $\frac{1}{5}$ but the number was constant within the $\frac{1}{6\text{-}7}$ as compared with the formula radula. Four of the radulae showed variations in the number of cusps on the second lateral teeth withi nthe radula but still within the range of the formula. Three radulae showed variations from the formula in the number of cusps on the first lateral teeth. Two of these showed variations within the radula. Variations as great as five were found in the number of cusps on the first lateral teeth from different radulae ($\frac{1}{10}$ in specimen 3f to $\frac{1}{5}$ in specimen 6f).

Angitrema armigera

Morphology of the radula. The radula of *A. armigera* showed the three characteristic regions. The worn region of the radula is not so distinct as in some of the other species. The formula most often found was

$$\frac{1\ -\ 1\ -\ 1\ -\ 1\ -\ 1\ -\ 1\ -\ 1}{9\text{–}10\quad 5\quad 3,\ 1,\ 2\quad 4,\ 1,\ 4\quad 2,\ 1,\ 3\quad 5\quad 9\text{–}10}.$$

Variations in the width of median teeth. A. In the same radula. Only one radula was mounted in such a condition that measurements could be made of the median teeth in all regions of the radula. The median tooth of the worn region were wider (144μ to 148μ) than the median teeth of the undeveloped region (100μ to 140μ) and the median teeth of the functional region were wider (148μ to 156μ) than the median teeth in either of the adjacent regions. Three radulae were mounted in such a condition that measurements of the median teeth in the functional and undeveloped regions could be made. In all radulae, the median teeth of the functional region (136μ to 148μ) were wider than the median teeth in the undeveloped region (108μ to 140μ). In radula, measurements could be made of median teeth in only the worn and functional regions. In this radula, the median teeth of the functional region (164μ to 168μ) were wider than the median teeth in the worn region (148μ to 160μ). The width of the median tooth is dependent upon its position in the radula.

B. In different radulae. Eighteen radulae were examined to determine variations in widths of median teeth. Variations as great as 30μ were found In one specimen, with a shell length of 18.9 mm., the widest median tooth measured was 126μ wide while in another specimen with a shell length of 27.0 mm. the narrowest median tooth measured was 156μ in width. Variations from smallest tooth of 120μ to 168μ for the widest tooth were found.

Correlation between widths of median teeth and size of shell. In all radulae from shells with lengths from 22.5 mm. 27.0 mm., median teeth with a width of 140μ were found while no radula from shells with a length less than 22.5 mm. possessed median teeth so wide as 140μ. When this overlapping of sizes is considered, the correlation of widths of median teeth with size of shell is obvious. The correlation of size of shell with width of median teeth is very definite in A. armigera.

Variations in number and arrangement of cusps on the various teeth. Three of ten radulae of *A. armigera* examined showed variations from the formula in the number of cusps on the median teeth. All three of these showed variations within the radula and all three showed some median teeth with the number of cusps indicated in the formula. Only two of the ten radulae examined showed variations from the formula on the number of cusps on the intermediate teeth. One of these showed variation within the radula while the other was constant within the radula. Two radulae showed variations within the number of cusps on the second lateral teeth. In each case, some of the second lateral teeth possessed the same number of cusps as indicated by the formula. The number of cusps on the median teeth of *A. armigera* is not highly variable.

Goniobasis livescens

Further extension in this investigation of the studies on the radulae of *G. livescens* show nothing differing from that shown in previous studies on the same species, Howe (1930).

V. Summary and Conclusions

1. A distinct increase in the size of the individual median teeth in radulae of *P. acuta, P. lewisii, P. canaliculatum, A. armigera, A. verrucosa,* and *G. livescens* accompanies increase in size of shell. The increase is fairly uniform from very small individuals to comparatively large individuals.

2. A distinct increase in the size of the central cusp of the median teeth accompanies increase in size of shell in *P. acuta* and *P. lewisii.* The increase in fairly uniform from very small individuals to comparatively large individuals.

3. Distinct differences in size of median teeth within the radulae often occur in *P. acuta, P. canaliculatum, P. lewisii, G. livescens, A. armigera,* and *A. verrucosa.* The width of the median tooth depends upon its position in the radula. The median teeth are widest in the functional region of the radula and narrowest in the undeveloped region of the radula.

4. Variations in the number of cusps on the various teeth of the radulae of *P. lewisii* from two different localities, *P. acuta, P. canaliculatum, A. armigera, A. verrucosa,* and *G. livescens* indicate that radular formulae are not safe criteria for specific diagnosis.

5. It is probable that width of median teeth may be used in generic diagnosis in the family Pleuroceridae if used wtih shell size. It would be necessary to state size of shell with description of radula. Size of median teeth has no value for specific diagnosis in the general of Pleurocera, Goniobasis, and Angitrema.

REFERENCES

BAKER, F. C. 1908—The Freshwater Mollusca of Wisconsin, Part I. Gastropoda. Wisconsin Geol. and Nat. History Survey Bull. **70**: 494 pp.

BOWELL, E. W. 1908—On the Radulae of the British Helicids. Proc. Malac. Soc. London **8**:125-127; 205-212; 379-387.

———1920—Further notes on Radulae. Ibid. **14**:46-47.

———1924—Radulae of Mollusca. Jour. Quekett Micros. Club, Ser. 2, **15**:57-64.

BOYCOTT, A. E. 1914—Radula of Hyalina. Jour. Conchol. (London) **14**:214-220; 232-236; 297-303.

CAWSTON, F. G. 1926—Gundlachia at Malvern, and an Examination of the Radulae of other Intermediate Hosts of the Trematoda Parasitic Worms of Natal. Trans. Royal Society South Africa **13**:39-42.

COOKE, A. H. 1918—On the Radulae of Acanthina, G. Fischer. Proc. Malac. Soc. London **13**:6-11.

FRIELE, H. 1879—Ueber die Variationen der Zahnstructur in der Gattung Buccinum. Jahrb. Mal. Ges. **4**:256-263.

GOODRICH, C. 1936—Goniobasis of the Coosa River, Alabama. Univ. of Mich. Museum of Zoology, Miscellaneous Publications No. **31**.

GWATKIN, H. M. 1914—Some Molluscan Radulae. Jour. Conchol. (London) **14**:139-148.

HOWE, SAM. W. 1930—A Study of the Variations in the Radulae of a Snail with particular Reference to the Size of the Median Teeth. The Nautilus **44**(2):53-66.

LIBOUR, M. V. 1906—On Variation in the Radulae of Certain Buccinidae. Jour. Conchol. (London), **11**::282-286.

STERKI, V. 1893—Growth changes in the Radula in Land Mollusks. Proc. Acad. of Nat. Sci. Philadelphia **46**:388-400.

VAN CLEAVE, H. J. AND EMILY M. RICHEY. 1936—Studies on the Radulae of the Genus Viviparus. Trans. Amer. Micr. Soc. **55**(2):223-229.

WILSON JR. COLLEGE,

CHICAGO, ILL.

North American Spiders of the Genus Agroeca

B. J. Kaston

The genus *Agroeca* is represented in North America by six known species, of which two are described as new in this paper. There are about a dozen Palearctic species according to Reimoser's catalog. Further collecting in America is certain to reveal other Nearctic species. *Agroeca pratensis* Emerton, and *A. ornata* Banks are the commonest and have the widest distribution. The latter species resembles closely the genotype, *A. brunnea* (Blackwall), especially in the structure of the epigynum. The most divergent of the American species, in this respect, is *A. minuta* Banks.

The types of the two new species described in this paper are from material in the collection of the Museum of Comparative Zoology at Cambridge, Mass. For the privilege of studying these and the types and other specimens of the other four American species thanks are due Professor Nathan Banks and Miss Elizabeth B. Bryant. I wish to thank Dr. W. J. Gertsch of the American Museum of Natural History for his kind assistance and for permitting access to material in his care. Dr. Helen H. Blauvelt very kindly loaned me some material from the Cornell University collection, and finally, facilities for this study, as well as financial support for some of the illustrative work have been furnished by the Connecticut Geological and Natural History Survey, through Dr. W. E. Britton, its Superitendent.

Agroeca Westring

Araneae Suecicae, 1861, Götheborgs Kongl. Vetensk.-och Vit.-Samh. Handl., Ny Tidsf., Hft. 7:311.

Genotype: *Agelena brunnea* Blackwall 1833.

Clubionid spiders of the subfamily Liocraninae. Carapace oval, longer than broad, not very high. Thoracic groove distinct, pars cephalica not sharply set off from pars thoracica, which is higher. Both eye rows very slightly procurved. The anterior may appear straight from above and is somewhat shorter than the posterior. Eyes of each row approximately equal and approximately equidistant. Median ocular area either slightly wider than long or slightly longer than wide, and broader behind than in front. Clypeus narrow. Chelicerae vertical, slightly geniculate, with boss. Promargin with three teeth, of which the proximal is generally smallest; the retromargin with two almost equal. Labium slightly wider than long, not attaining middle of endites. The maxillary endites more or less parallel, rounded on outer margin and provided with thick scopulae. Sternum almost as broad as long, truncate in front. Legs in order 4123, with very little difference in length between the second and third. Scopula lacking or very weak on tarsi. Claw tufts lacking. Trichobothria numerous on tibiae, metatarsi, and tarsi. Tibia I with two pairs, and metatarsus I and II with two or three pairs of ventral spines. Abdomen oval,

usually widest behind the middle. Anterior spinnerets thicker than posterior and slightly shorter. At times they may appear to be rather widely separated at base simulating the condition in the Gnaphosidae. In the male palpal organ, associated with the short embolus is a thin, transparent, membranous structure (terminal apophysis?), and a hooked median apophysis. The epigynum is relatively simple, exhibiting externally one or two pairs of tubules variously curved.

In color pattern the American species resemble one another fairly closely. The ground color is orange-brown and the markings are gray and black. The carapace (Fig. 1) is bordered by a black marginal stripe becoming less conspicuous on the cephalic part. Extending along the radial furrows from the thoracic groove not quite to the edges of the carapace are dusky blotches. A pair of dusky bands extends to the second eye row. In *A. ornata* the dusky marks are quite faint. While there is considerable variation among individuals, reference to figures 1 to 6 obviates the necessity for a verbal description of the abdominal patterns.

Specimens are generally found running about under old leaves on the ground and can be sifted from debris in winter and early spring when both sexes are usually mature.

Agroeca can be distinguished from the related genus *Apostenus* in having fewer leg spines, lacking the two long spatulate hairs beneath the tarsal claws, (Fig. 15), and in having much smaller eyes. From Keyserling's diagnosis of his genus *Hilke* the only character which can be used to distinguish it from *Agroeca* would seem to be the weak recurvature of the anterior row of eyes. But Keyserling definitely stated that they appeared recurved from above! An examination of the type of Keyserling's *trivittata* at the Museum of Comparative Zoology reveals the fact that seen from in front this eye row is procurved! Therefore, following Gertsch, *Hilke* is here considered a synonym of *Agroeca*. In 1932 Simon (Arachnides de France, vol. 6) removed *lineata* Simon and *striata* Kulczynski from*Agroeca* to the new genus *Agraecina* [sic]. In the latter group the anterior metatarsi are furnished with only two pairs of ventral spines, the distal pair being lacking. It is also stated that the tibial apophysis of the male palpus is long, thin, and pointed, while that of *Agroeca* is more robust and shorter. It is further intimated that the palpal organ is quite convex, at least at the base, and seen in profile is wider than the cymbium. However, the drawings accompanying the descriptions do not corroborate these remarks.

Though in 1929 Roewer (Araneae, in Tierwelt Mitteleuropas) had listed the male of *striata* among those with three pairs of ventral spines on the anterior metatarsi, in 1937 Reimoser (Clubionidae, in Tierwelt Deutschlands) followed Simon in placing *striata* with those having only two pairs. Possibly there is variation, and from a study of American species it would seem that *Agraecina* can hardly stand unsuppressed. For in the species with two pairs *(emertoni, trivittata,* and *minuta)* rather than being long and thin the tibial apophyses are considerably *stouter* than those of the species with three pairs of spines!

Species described as *Agroeca* which belong elsewhere include *tristis* Keyserling 1887, from Maryland, and *walsinghami* Cambridge 1874, from Oregon. Both belong in *Castianeira*.

KEY TO THE SPECIES OF AGROECA

1a. Metatarsi I and II with three pairs of ventral spines, in length the basal two pairs twice the thickness of the segment, the distals somewhat shorter ------ 2
1b. Metatarsi I and II with only two pairs of ventral spines, hardly longer than the thickness of the segment ---------- 6
2a. Females ---------- 3
2b. Males[1] ---------- 5
3a. Patella III with a retrolateral spine. Epigynum as in figure 20 ---------- *spinifer*
3b. Patella III without a retrolateral spine. Epigynum not as above ---------- 4
4a. Epigynum much longer than wide, (Fig. 17) ---------- *ornata*
4b. Epigynum about as wide as long, (Fig. 18) ---------- *pratensis*
5a. Patella III and IV with a retrolateral spine. Tibial apophysis shorter than thickness of tibia (Figs. 9 and 13) ---------- *pratensis*
5b. Patella III and IV without a retrolateral spine. Tibial apophysis as long as thickness of tibia (Figs. 8 and 12) ---------- *ornata*
6a. Patella IV without a retrolateral spine ---------- *emertoni*
6b. Patella IV with a retrolateral spine ---------- 7
7a. Epigynum with a thickened lip at the anterior end (as in *emertoni*). Tibial apophysis with sides subparallel to near tip. (Fig. 21) ---------- *trivittata*
7b. Epigynum as in Fig. 16. Tibial apophysis triangular, and very broad at base (Fig. 11) ---------- *minuta*

Agroeca ornata Banks
Figs. 3, 8, 12, and 17

Agroeca ornata Banks 1892 Proc. Acad. Nat. Sci. Philadelphia, 44:23, pl. 1, f. 68-68a ♀. Banks 1895 Jour. New York Ent. Soc., 3:80. Banks 1910 Bull. U. S. Nat. Mus., 72:12. Petrunkevitch 1911 Bull. American Mus. Nat. Hist., 29:443. Emerton 1919 Trans. Roy. Canadian Inst., 12:332. Crosby and Bishop 1928 Cornell Univ. Agr. Exp. Sta. Mem., 101:1061. Chamberlin and Ivie 1933 Bull. Univ. Utah, 23 (4), Biol. Ser., 2(2):40. Chickering 1934 Pap. Michigan Acad. Sci., 19:579.

Agroeca repens Emerton 1894 Trans. Connecticut Acad. Sci., 9:412, pl. 2, f. 6-6a ♀. Simon 1897 Hist. Nat. Ar., 2:141. Bryant 1908 Occ. Pap. Boston Soc. Nat. Hist., 7(9):72. Emerton 1930 Nantucket Maria Mitchell Assoc. Publ., 3(2):170.

Agroeca pratensis Emerton 1909 Trans. Connecticut Acad. Sci., 14:220 (in part, males of *ornata* confused with males of *pratensis*).

The *male* is here described for the first time. For a long while Emerton and others had confused the males of *ornata* and *pratensis*. It was even thought that perhaps the females were merely dimorphic forms of the same species, of which the males were all one form. Dr. W. J. Gertsch was the first to recognize the two males as distinct, and I have taken the two sexes together without individuals of *pratensis* mixed in the same lot.

Total length 4.4 mm. Carapace 2.2 mm. long, 1.8 wide and narrowed to .87 at clypeus. Highest at dorsal groove. The black marginal line is

[1] The male of *spinifer* is unknown.

present, but the dusky markings along the radial furrows, typical for the genus, are very faint in this species.

Front row of eyes practically straight. Second row longer than first in ratio 41:38; medians of each row slightly smaller than laterals. Laterals of each side separated by less than a diameter. Median ocular area wider behind than in front (17:15) and longer than wide (18:17). Height of clypeus about equal to a radius of anterior lateral eye. Labium wider than long (23:19) not reaching to middle of maxillary endites. Sternum longer than wide (41:36), truncate in front, bluntly pointed behind between the fourth coxae which are almost contiguous.

	Femur	Pat. + Tib.	Metatarsus	Tarsus	Total
Leg I	1.81	2.48	1.31	1.02	6.62 mm.
II	1.69	2.04	1.23	.91	5.87 mm.
III	1.69	1.84	1.46	.82	5.80 mm.
IV	2.13	2.77	2.42	1.02	8.34 mm.

Tibial index of leg I is 11.8; of leg IV, 11.9.

Spines as follows: Leg I, femur dorsal 1-1-1, prolateral 1d; tibia ventral 2-2; metatarsus ventral 2-2-2. Leg II, femur as leg I; tibia ventral 2-2, those nearer the prolateral side shorter than those near the retrolateral, prolateral 1d; metatarsus ventral 2-2-2, prolateral 1 basal. Leg III, femur dorsal 1-1-1, prolateral 1-1, retrolateral 1-1; tibia dorsal 1 basal, prolateral 1-1, retrolateral 1-1, ventral 2-2-2; metatarsus dorsal 2-2-2, retrolateral 1-1-1, prolateral 1-1-1, ventral 2-2-2. Leg IV, femur dorsal 1-1-1, prolateral 1-1, retrolateral 1d; patella retrolateral 1; tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-2; metatarsus dorsal 2-2-2, prolateral 1-1-1, retrolateral 1-1, ventral 2-2-2.

Abdomen with two rows of irregular dark blotches on dorsum, venter pale.

The patella of the palpus is narrower than the tibia. The tibial apophysis is about as long as the thickness of segment and is drawn out to a long point. The plate-like structure bearing the embolus is much broader than in *pratensis*.

Female. Total length 5.8 mm. Carapace 2.3 mm. long, and 1.8 wide. Essentially like male in general appearance. However, the chelicerae are somewhat more geniculate, and the dusky marks on the radial furrows of the carapace are more distinct. Tibial index of leg I is 13.3, of leg IV, 11.5.

Epigynum longer than wide. From the ventral aspect only two thick tubules can be distinguished; these are subparallel and are practically in contact along the mid line in the anterior half. Of the American species this one comes closest in structure of epigynum to the genotype, *brunnea*.

Distribution. Type locality for *ornata* is Ithaca, N. Y., for *repens* is Laggan, Alberta. This species has been reported from Michigan by Chickering, from various localities in New York by Crosby and Bishop, from Massachusetts by Bryant, and by Emerton; from Utah by Chamberlin and Ivie, and from Quebec and California by Emerton. In addition there are specimens at the Museum of Comparative Zoology from Vermont, New Hampshire and Ontario; at the American Museum of Natural History from Minnesota, Iowa, Pennsylvania, New Jersey and Colorado; at Cornell from Wisconsin, and I have them from Connecticut.

Agroeca pratensis Emerton

Figs. 4, 9, 13 and 18

Agroeca pratensis Emerton 1890 Trans. Connecticut Acad. Sci., 8:190, pl. 6, f. 7-7e ♂ ♀. Banks 1892 Proc. Acad. Nat. Sci. Philadelphia, 44:23. Banks 1895 Jour. New York Ent. Soc., 3:80. Simon 1897 Hist. Nat. Ar., 2:141. Emerton 1902 Common Spiders, p. 11, f. 33-36 ♂ ♀. Banks 1907 Indiana Dept. Geol. Nat. Hist. Res., 31st Ann. Rpt., p. 737. Bryant 1908 Occ. Pap. Boston Soc. Nat. Hist., 7(9):72. Emerton 1909 Trans. Connecticut Acad. Sci., 14:220 (in part). Banks 1910 Bull. U. S. Nat. Mus., 72:12. Petrunkevitch 1911 Bull. American Mus. Nat. Hist., 29:443. Comstock 1912 Spider Book, p. 574. Emerton 1913 Appalachia, 12(2):156. Emerton 1919 Trans. Roy. Canadian Inst., 12:332. Barrows 1924 Ohio J. Sci., 24:311. Crosby and Bishop 1928 Cornell Univ. Agr. Exp. Sta. Mem. 101:1061. Emerton 1930 Nantucket Maria Mitchell Assoc. Publ., 3(2):170. Worley and Pickwell 1931 Univ. Nebraska Stud., 27:76. Elliott 1932 Proc. Indiana Acad. Sci., 41:427. Chamberlin and Ivie 1933 Bull. Univ. Utah, 23(4), Biol. Ser. 2(2):40. Chickering 1934 Pap. Michigan Acad. Sci., 19:579. Fox 1938 Iowa State Coll. J. Sci., 12:238.

This species resembles *ornata* but averages slightly larger in size. A representative female measures 6.9 mm. long, and a male 5.4 mm. Also, the median ocular area is relatively wider behind than in *ornata*, and the area is slightly wider than long. The spination of the legs is approximately the same, the chief difference being the presence of a spine on the retrolateral surface of patella III in the male. The pattern on the abdomen differs chiefly in that *pratensis* has a faint median longitudinal stripe on the basal half anterior to the paired spots (Fig. 4).

Epigynum about as broad as long. Towards the posterior end is a pair of tubules, each tube curved in the form of a "U," with the open ends approximated (Fig. 18).

The patella of the palpus is thicker than the tibia. The tibial apophysis is thicker at the base than in *ornata*, and is shorter. The plate-like structure bearing the embolus is not as broad as in *ornata*.

Distribution. Type locality, West Quincy, Mass. This species has been reported from Michigan by Chickering, various localities in New York by Crosby and Bishop, from Maine, New Hampshire and Rhode Island by Bryant, from Ohio by Barrows, from Indiana by Banks and by Elliott, from Utah by Chamberlin and Ivie, from Nebraska by Worley and Pickwell, from Quebec by Emerton, and from Washington, D. C., and British Columbia by Fox. In addition there are specimens in the Cornell collection from Minnesota and Colorado, and I have them from Connecticut.

Agroeca spinifer sp. nov.

Figs. 2 and 20

Female. Very much like *pratensis* in general appearance. Total length 5.4 mm. Carapace 2 mm. long and 1.5 mm. wide. Median ocular area slightly longer than wide (21:20). Like *pratensis* and *ornata* the metatarsi I and II have three pairs of ventral spines. It differs from the females of those two species in having a spine on the retrolateral surface of patella III, and especially in the distinct epigynum (Fig. 20).

This species is known only from the holotype female collected at Fillmore, Utah, by R. V. Chamberlin (probably during August-September 1917).

Agroeca trivittata (Keyserling)

Figs. 5 and 21

Hilke trivittata Keyserling 1887 Verh. k. k. zool.-bot. Ges. Wien, 37:444, pl. 6, f. 17 ♀. Marx 1890 Proc. U. S. Nat. Mus., 12:513. Simon 1897 Hist. Nat. Ar., 2:146. Banks 1910 Bull. U. S. Nat. Mus., 72:13. Petrunkevitch 1911 Bull. American Mus. Nat. Hist., 29:489. Comstock 1912 Spider Book, p. 575. Worley 1932 Univ. Washington Publ. Biol., 1(1):49.

Herpyllus oabus Chamberlin 1919 Ann. Ent. Soc. America, 12:246, pl. 16, f. 6 ♂.

Agroeca hesperia Banks 1921 Proc. California Acad. Sci., ser. 4, 11:101, f. 4 ♂♀.

Rachodrassus flavus Chamberlin and Gertsch 1928 Proc. Biol. Soc. Washington, 41:178. Chamberlin and Woodbury 1929 Proc. Biol. Soc. Washington, 42:134, pl. 2, f. 2 ♂♀.

Agroeca oaba Gertsch 1935 American Mus. Nov., 805:10.

Agroeca trivittata Gertsch 1935 American Mus. Nov., 805:10.

Female. Total length 5.8 mm. Carapace 2.6 mm. long and 2.0 wide. Median ocular area wider than long. Anterior row of eyes when seen from above appear very slightly recurved. AME smaller than ALE in ratio 7:10. PME separated by a diameter.

Spines on legs as follows: Leg I, femur dorsal 1-1-0, prolateral 1d; tibia ventral 2-2; metatarsus ventral 2-2. Leg II, femur like I; tibia ventral 1r-2-1p (or 1r-1r-1p), prolateral 1d; metatarsus ventral 2-2. Leg III, femur dorsal 1-1-1, prolateral 1-1, retrolateral 1-1; patella retrolateral 1; tibia dorsal 1 basal, prolateral 1-1, retrolateral 1-1, ventral 1p-2-2; metatarsus dorsal 2-2-2, retrolateral 0-1-1, ventral 2-2-2. Leg IV, femur dorsal 1-1-1, prolateral 1-1, retrolateral 1d; patella retrolateral 1; tibia dorsal 1-1-0, prolateral 1-0, retrolateral 1-1, ventral 1p-2-1p; metatarsus dorsal 2-2-2, prolateral 0-1-1, retrolateral 1-0-1, ventral 2-2-2.

Epigynum with a thickened raised lip at the anterior end (as in Fig. 19 for *emertoni*).

Male. Total length 4 mm. Carapace 1.9 mm. long and 1.5 wide. Similar in general to the female including the presence of a spine on the retrolateral surface of patella III and IV.

Palpus with tibia slightly longer than the patella. Tibial apophysis with sides subparallel to near the tip, gently rounded distally. Palpal organ hardly distinguishable from that of *emertoni* (Fig. 10).

Distribution. The type of *Hilke trivittata* is from California (it is labeled in Keyserling's hand "*Liocranum trivittata*"). The types of *Herpyllus oabus* and *Rachodrassus flavus* are from Utah. That of *Agroeca hesperia* is from California. This species is also recorded from Washington by Worley, and in addition the American Museum has specimens from Arizona.

I was unable to procure specimens identified as Chamberlin's *Herpyllus oabus* or *Rachodrassus flavus*, but from the published descriptions and figures it seems correct to follow Gertsch in synonymizing these under *trivittata*. As

stated above, occasional specimens of *Agroeca* have the anterior spinnerets somewhat separated simulating the condition in the Gnaphosidae. Furthermore, in Chamberlin's review of Gnaphosid species (1922, Proc. Biol. Soc. Washington, 35: 145-172) *Herpyllus oabus* is not listed.

Agroeca emertoni sp. nov.

Figs. 1, 10, 14, 15, 19

Agroeca "unknown species" Emerton 1930 Nantucket Maria Mitchell Assoc. Publ., 3(2):170.

This species closely resembles *trivittata* especially in the structure of epigynum and palpus. The two species may be distinguished as follows: the tibial apophysis in *emertoni* has convergent, rather than parallel, sides. The abdomen has larger light colored areas (cf. Figs. 1 and 5). The spination under tibia II is 1r-1r-0. The spines are lacking from patellae III and IV. The AME are larger, their ratio to ALE being 9:10 rather than 7:10. Finally, the PME are separated by more than a diameter.

Total length of male 4.2 mm. Carapace 2.2 mm. long and 1.65 wide. Median ocular area longer than wide. Palpus with tibial apophysis not quite half as long as tibia. Palpal organ as in figure 10.

Female 4.5 mm. long. Essentially like male.

Distribution. Holotype male with two female paratypes collected on the island of Nantucket, Massachusetts, by J. H. Emerton, May 16, 1928. Several immature paratypes collected by him in the same place, August 2, 1929. One female was collected by the author at Branford, Connecticut, June 6, 1937.

This species was recorded by Emerton as "unknown" in the last of his many papers on spiders. No doubt it would have been described in a subsequent publication had he lived.

Agroeca minuta Banks

Figs. 6, 7, 11, and 16

Agroeca minuta Banks 1895 Jour. New York Ent. Soc., 3:80 ♀. Simon 1897 Hist. Nat. Ar., 2:141. Banks 1910 Bull. U. S. Nat. Mus., 72:12. Petrunkevitch 1911 Bull. American Mus. Nat. Hist., 29:443. Comstock 1912 Spider Book, p 575. Barrows 1918 Ohio J. Sci., 18:299. Crosby and Bishop 1928 Cornell Univ. Agr. Exp. Sta. Mem., 101:1061. Elliott 1932 Proc. Indiana Acad. Sci., 41:427.

Apostenus acutus Emerton 1909 Trans. Connecticut Acad. Sci., 12:220, pl. 9, f. 7-7c ♂. Banks 1910 Bull. U. S. Nat. Mus., 72:12. Petrunkevitch 1911 Bull. American Mus. Nat. Hist., 29:449. Comstock 1912 Spider Book, p. 574. Crosby and Bishop 1928 Cornell Univ. Agr. Exp. Sta. Mem., 101:1061.

Male. Total length 3.3 mm. Carapace 1.64 mm. long and 1.34 wide. Median ocular area as long as wide. Patella III and IV with a spine on retrolateral surface, and metatarsus I and II with two pairs of ventral spines.

Palpus with tibial apophysis broad at base as figured. Cymbium with sides subparallel rather than converging as in the other species, and gently

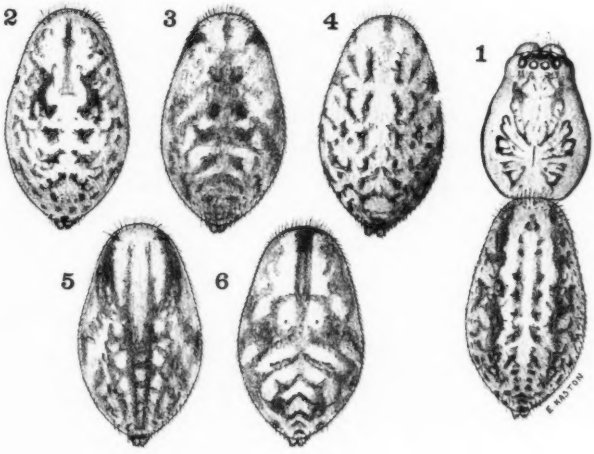
rounded distally. The palpal organ extends beyond the alveolus ventral to the tibia.

Female. Total length 3.5 mm. Similar to male. Epigynum with a pair of thin tubules each making almost a complete circle, and another pair posterior to these each describing an arc of less than half a circle (Fig. 16).

In structure of palpus and epigynum this species seems to be less related to the others of the genus than the others are to one another. It is the darkest species, the ground color being dark brown and the markings quite black. The legs have all the femora and tibia I black and patellae brown. Other tibiae, as well as metatarsi are black at ends only.

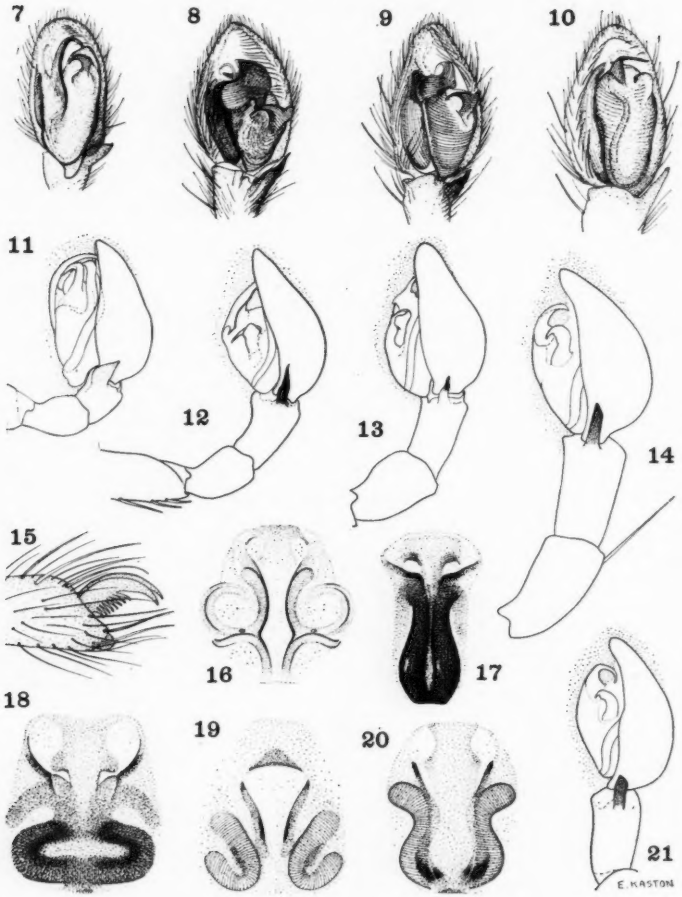
Distribution. The type locality for *minuta* is Long Island, New York; for *Apostenus acutus* is New Haven, Connecticut. It has been recorded from Ohio by Barrows, and from Indiana by Elliott. In addition the American Museum of Natural History has specimens from New Jersey.

BRENAU COLLEGE,
GAINESVILLE, GEORGIA.



FIGURES

1. *A. emertoni*, dorsal aspect of body.
2. *A. spinifer*, dorsal aspect of abdomen.
3. *A. ornata*, same.
4. *A. pratensis*, same.
5. *A. trivittata*, same
6. *A. minuta*, same



FIGURES

7. *A. minuta*, left palp ventral aspect.
8. *A. ornata*, same.
9. *A. pratensis*, same.
10. *A. emertoni*, same.
11. *A. minuta*, left palp, retrolateral aspect.
12. *A. ornata*, same.
13. *A. pratensis*, same.
14. *A. emertoni*, same.
15. *A. emertoni*, distal end of tarsus II.
16. *A. minuta*, epigynum.
17. *A. ornata*, same.
18. *A. pratensis*, same.
19. *A. emertoni*, same.
20. *A. spinifer*, same.
21. *A. trivittata*, left palp, retrolateral aspect.

Four New Arthropods from New England

Arthur Paul Jacot

Diplopoda

Professor of Forest Soils Harold J. Lutz of Yale University has for the past three years been studying the habits of a millipede of the genus Fontaria which he finds to be fairly abundant in the pine plantations of the Yale Forest at Keene, New Hampshire. As it represents a new species of the *F. coriacea-F. trimaculata* group, I take pleasure in naming it after its discoverer:

Fontaria lutzi sp. nov.

Differs from *F. coriacea* and *F. trimaculata* in that the pair of intromittent organs apparently lack the proximal spine; proximal or bulb bristles long and numerous, overlapping across median plane; major spine long and slender, crossing its neighbor twice, proximal third with a row of bristles the length of which exceeds the diameter of the spine at that point (left figure); lateral spine short, usually straight, directed mesad. The proximal spine is actually well developed but on mesal face of shaft of penis so that it is invisible in ventral aspect, being eclipsed in part by the bulb (base of major spine) and by the long bristles of the bulb. If one of the organs be removed and the mesal aspect examined (right hand figure—most bristles omitted) the proximal spine will be seen springing from center of shaft (which, in life, is directed cephalocaudad) directed downward (upward in normal, ambulatory position of animal) and backward, and recurved so as to terminate against base of bulb; ventral face of shaft bearing one bristle (right figure, which shows lateral spine foreshortened).

The color pattern resembles that of *F. trimaculata*, that is posterior half

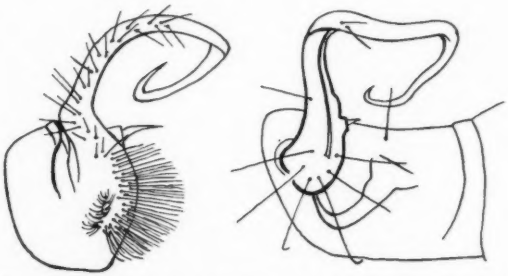


Fig. 1. *Fontaria lutzi* sp. nov., male organ, left figure ventral aspect, right figure mesal aspect when removed (most bristles omitted).

of lateral carinae and a semioval median spot on posterior edge of dorsal scutes yellow to orange or even rose-orange; hour-glass of first scute usually incomplete; anal scute yellow only along posterior two-thirds of median line.

Posterior coxae with prominent angle but no spine.

The figure on the left is as seen in normal ventral aspect when animal is killed in boiling water (which causes these organs to stand out more than when killed in alcohol). The left half of the main body is the caudal end of the shaft, the right half (bearing the long bristles is the bulb (base of the major spine). Between them are two or three low ridges and their intervening grooves. The figure at the right is mesal aspect as seen when one organ is removed. The prow at right of base of major spine is caudal end of shaft (mesal aspect). The broad rectangular portion to right of the major spine is the shaft (mesal aspect) with the proximal spine on its mesal face. Only enough bristles are figured to give an idea of their length and direction. The two bristles on major spine are the distalmost.

Cotypes: Seven males and several females from white pine plantation of Yale Forst (compartment I), Keene, N. H. To be deposited at Boston Society of Natural History and Peabody Museum, Yale University.

This seems to represent a distinct New England species. The type locality of *F. coriacea* is Virginia, that of *F. trimaculata* is Susquehanna County, Pennsylvania. The penis of *F. coriacea* and *F. trimaculata* has been adequately figured by Wood (Myriapoda of North America) and by Williams and Hefner (The Millipedes and Centipedes of Ohio).

Collembola

During the month of March (1937) Jack Whiteside collected an entire colony of *Formica exsectoides* from Branford, Connecticut. Among the commensals were about sixty *Lepidocyrtus violentus rolfsi* Mills 1932. I refer *L. rolfsi* to the rank of subspecies because the only invariable and substantial differential character is the tenent hair which though clean cut, characteristic, and not changeable through subsequent manipulation, does not, alone, warrant regarding the bearer as a distinct species.

There were also two specimens of a species of Arrhopalites which is undescribed and may be recognized as follows:

Arrhopalites whitesidei sp. nov.

Dark pigment entirely lacking (white in alcohol); no eyes discernible; dentes with nine short bristles and five spines of three calibers disposed as in the accompanying figure wherein these spines are foreshortened (being more or less erect); mucro with well developed distal cup, and the lateral row of denticles interrupted and forming two distinct series, the proximal bearing the coarser denticles; mesal row continuous but the size of the denticles of two distinct calibers, as in the figure.

Cotypes: Two specimens mounted on one slide in gum arabic medium,

to be deposited at the State Agricultural Experiment Station, New Haven, Connecticut.

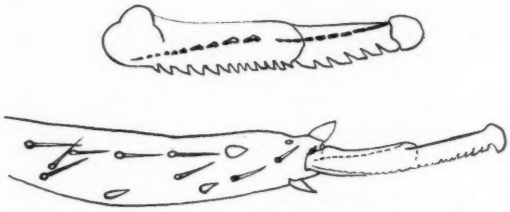


Fig. 2. *Arrhopalites whitesidei* sp. nov., mucro and dens, dorsal aspect, (upper figure, mucro only, slightly from the side).

Acarina

The following mites from spruce litter samples taken from the Gale River Experimental Forest (between Mount Lafayette and the Ammonoosuc River), Pierce Bridge, N. H. are undescribed.

Coccorchestes gen. nov.

Related to Speleorchestes (Trägårdh 1909) but with a pair of bristles on rostrum and four pairs (including the long pseudostigmatic organs) on cephaloprothorax; no eyes; abdomen short without distinct transverse folds, with normal number of bristles (32) which are clavate; epimera IV as in Speleorchestes; distal segment of palps tapering-constricted.

Type: *C. humicolus* sp. nov.

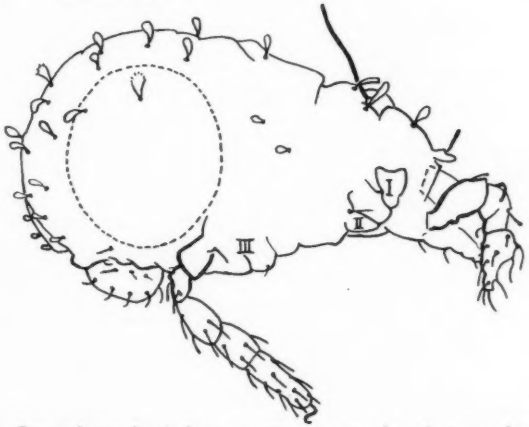


Fig. 3. *Coccorchestes humicolus* gen. nov. sp. nov., lateral aspect, legs I to III omitted; egg indicated by broken line.

Coccorchestes humicolus sp. nov.

Without pigment; rostral bristles slenderly clavate, exopseudostigmatic bristles longer, stouter, postpseudostigmatic bristles still stouter, prepseudostigmatic bristles short and broadly clavate; pseudostigmatic organs filiform, as long as cephaloprothorax; first transverse row of bristles of abdomen with lateral two bristles (each side) widely separated from mesal pair, the lateral longer and more slender than the others (foreshortened in figure); bristles of abdomen arranged in transverse rows from anterior to posterior to the number of 6, 4, 4, 6, 6, 6; paranal bristles smaller; anal bristles shorter, barely clavate (3); genital bristles five, simple; aggenital two; tarsi I with long prone spine; size minute: length (to tip of rostrum) 0.164 mm., breadth 0.74 mm.

Cotypes: Three specimens from bottom of humus (H-) layer of spruce woods, Gale River Exp. Forest, Pierce Bridge, N. H.; taken July 19th, slide 37F1-3Hb-2. To be deposited at the National Museum.

Adoristes ovatus ammonoosuci subsp. nov.

Differs from the species (Koch, fasc. 30:24) in having more approximate lamellae so that sides of cephaloprothorax are visible beyond them (laterad); rim of lamellae sharp (not thickened) forming a sharply pointed cusp; channel at base of lamellae extending some distance anteriad of insertion of lamellar bristles; interlamellar bristles short, stout; flange of shoulder of ventral plate not projecting beyond shoulders of notogaster (posteriad of pseudostigmata).

Cotypes: Eleven specimens from spruce litter, Gale River Exp. Forest, Pierce Bridge, N. H.; taken July 19th, slide 37F1-L-25. To be deposited at the National Museum.

Northwestern Forest Exp. Station,
New Haven, Conn.

Parasites of Some Minnesota Cricetidae and Zapodidae, and a Host Catalogue of Helminth Parasites of Native American Mice

Arnold B. Erickson

Introduction

The problem of parasites of the mice native to North America has been much neglected in the past despite the economic and ecological importance of these rodents. True, much has been written concerning the losses due to field mice; and their importance in human and animal disease has not been overlooked. The fact that they serve as key animals in the food chain and are, at the time of their cyclic high, preyed upon by the carnivores almost to the exclusion of other animals, has also been emphasized by various workers. Whether their cycles of abundance and dearth are influenced by the same force or forces as those which govern the snowshoe hare and the ruffed grouse populations, is a mooted question.

The phenomenal increase of wild mice in the late summer and fall of certain years has been noted from times long past. In order to gain some information concerning these sudden outbreaks and die-offs of wild mice, Elton and his associate (1931) trapped large numbers of three species of field mice and examined them for ectoparasites, endoparasites, protozoa, and bacterial infections. They came to no definite conclusions concerning the role that these agents play in the cyclic phenomenon.

In 1934, however, Findlay and Middleton, and in 1935, Elton, Davis, and Findlay found that epidemics among voles *(Microtus agrestis)* in Britain were due to a protozoan infection of the brain due to a *Toxoplasma.*

In 1927 N. E. Wayson of the U. S. Public Health Service concluded that the epizootic among *Microtus californicus* in California was due to *Bacillus murisepticus* or *Bacillus rhusiopathiae suis.*

In 1936 Harkema published a list of the external and internal parasites of the white-footed mouse *(Peromyscus leucopus leucopus)* of his region, North Carolina.

Other investigators, but especially M. C. Hall, have added to our knowledge of parasites of rodents by compiling the published material.

In the present work the chief emphasis has been placed on the parasites and parasitism of the various species of field mice, but the influence that these parasites might exert on the abundance and scarcity of the mice has been constantly kept in mind. At all times, too, the activities and habits of the mice have been studied.

In order to make the recorded knowledge of the internal parasites of mice native to North America more accessible, a host-parasite catalogue has

been prepared. In some cases experimental forms have been included, and they are indicated as such. The number in parenthesis following the parasite entry refers to a corresponding number in bibliography. Harkema's list of rodent parasites (1936) has been of much value in the preparation of the present list.

The writer wishes to express his appreciation to Dr. W. A. Riley under whose direction this work was caried on, and who many times helped with suggestions, criticisms, and kindly advice. He is also indebted to Dr. C. E. Mickel who identified the insects from insect parts that were taken from the digestive tracts of mice, and to Mr. Lawrence Penner for specimens of mice parasites and for permission to include in the host-parasite catalogue of mice his unpublished data.

Source of Material and Methods of Trapping

The parasites of five species of native field mice, 91 individuals, were studied in the investigation: 22 jumping mice *(Zapus hudsonius hudsonius)*, 18 meadow mice *(Microtus pennsylvanicus pennsylvanicus)*, 38 Canadian deer mice *(Peromyscus maniculatus gracilis)*, 10 northern white-footed mice *(Peromyscus leucopus noveboracensis)*, and 3 red-backed mice *(Clethrionomys gapperi gapperi)*. Most of the mice were trapped in Anoka, Hennepin, Ramsey, and Pine Counties, Minnesota.

Most of the Canadian deer mice were trapped in Pine County along the foundations of two buildings about fifty feet apart. The traps on the area were set each night about 8:30 p.m. and emptied each morning at 7:00 a.m. In many instances the mice had died a short time before 7:00 a.m. or were still struggling. This fact lends some support to the idea that the deer mouse may be quite as active in the early morning hours as in the darker hours of night. Further support was added to the idea in 1937, when several deer mice were trapped after 7:00 a.m.; and one was caught at noon.

Other methods than snap traps were employed in the capture of jumping mice in Pine County. For example, the were occasionally captured by hand in open, dry fields in the proximity of water. When pursued they are adpet at dodging, but their continuous bounding and semiupright position make them an easy mark to follow.

Another method for the capture of jumping mice was discivered by chance. It so happened that a telephone line was being laid through one of the trapping areas which consisted of low, moist, rank meadows alternating with dry sandy ridges. Holes for telephone poles were frequently dug in the afternoon and left over night. During the day a few jumping mice were seen, but judging from the numbers that were found in the pole holes the next morning, the population of the area was dense. From one hole, for example, 7 jumping mice, 4 meadow mice, one long-tailed shrew *(Sorex cinereus cinereus)*, and 12 leopard frogs *(Rana pipiens)* were recovered. In another hole 5 jumping mice and one long-tailed shrew were found. In nearly all of the holes there were jumping mice.

Food of Mice

Although the food of the deer mouse is probably chiefly vegetable, insects appear to form one of the staples of its summer diet. Particles of chitin, whole insect legs, and antennae, as well as the remains of spiders, have been found in the digestive tracts of Minnesota specimens.

The fact that the digestive tract of nearly every deer mouse contained much grit is significant. The stomach and small intestine held, as a rule, many fewer grits that the caecum and the large intestine, where the grits apparently tended to concentrate. It appeared as though the mice had eaten grits to satisfy a need for mineral food. The digestive tracts of other species of mice contained grits likewise.

The fact that jumping mice were very abundant in certain dry fields throughout the day could not be explained at the time, especially since some writers regard them as being chiefly nocturnal. However, during the examination of the digestive tract for helminths, insect parts were frequently found. The parts were identified as the antennae of ants, the elytra of ground beetles, and the legs of beetles of the families Alleculidae and Elateridae. The mice, no doubt, had been stalking by day the beetles and ants that abounded in these fields.

Technique of Examination and Fixation

The internal organs of the mice were placed in physiological saline solution or in alcohol, if the mouse had been preserved in alcohol, and examined under the binocular. About 57 specimens of mice from Pine County were preserved in formalin or in alcohol. Nematodes from these preserved mice as well as nematodes from fresh specimens were placed in cold 70% alcohol. Some nematodes were cleared in glycerine; others were stained in Ehrlich's acid haematoxylin, dehydrated by the string siphon method, and cleared in wintergreen oil. Cestodes were killed in hot corrosive sublimate; or if dead, they were placed in cold 70% alcohol and then stained in Ehrlich's acid haematoxylin.

Nematodes recovered from mice that had been preserved in formalin required special treatment for staining. Formalin hardens the cuticle and renders nematodes more or less impervious to the action of stains. This is especially true of the larger nematodes with thick cuticles. Formalin-preserved nematodes can lie for days in Ehrlich's acid haematoxylin or in borax carmine and not absorb the stain. If the cuticle is pricked in sundry places, the stain will penetrate for a small area around the apertures. Besides puncturing the cuticle it is usually necessary to place the nematode in an oven at 58° C. before the stain penetrates the entire worm. The time required for staining at 58° C. depends on the size of the worm, the thickness of the cuticle, and the degree of formalin fixation. Small nematodes will stain in a few hours; larger nematodes may require 48 hours and still be unevenly stained.

Once the formalin-fixed nematode is stained, the problem of destaining must be solved. One-tenth of a per cent hydrochloric acid in 70% alcohol does not destain, or destains very slowly the larger nematodes. Even a one

per cent to 5 per cent solution of acid in alcohol destains the nematode slowly. The destaining process can be speeded up by placing the worms in one per cent acid alcohol in an oven at 58° C. Destaining, like the staining of formalin-fixed specimens, is apt to be patchy.

Formalin fixation does not affect the transparency of worms that are cleared in glycerin and sealed with Noyer's cement. Perhaps the one redeeming feature of formalin fixation is the fact that it renders delicate nematodes less susceptible to injury by hasty dehydration.

Parasites of Zapus hudsonius hudsonius

Of the 22 specimens of jumping mice examined, only one, a female taken in Pine County on August 31, 1936, contained internal parasites. This mouse presented a most unusual case of concurrent parasitism. All in all, she harbored 41 nematodes of two species. The worm burden must have been terrific, especially since the nematodes are large.

Besides these nematodes, the writer has in his possession a fluke *(Notocotylus hassali)* that was taken from a jumping mouse that was trapped at Douglas Lake, Michigan by Mr. L. A. Penner. It will be considered with the Minnesota parasites of the jumping mouse.

Notocotylus hassalli McIntosh and McIntosh

The trematode genus *Notocotylus*, characterized by a single sucker and the posterior position of the testes and the ovary, has been found in muskrats by Barker, in birds by several workers, and in *Microtus pennsylvanicus p.* by McIntosh and McIntosh. The last two workers have recently described the form from *Microtus* as a new species, *Notocotylus hassalli* McIntosh and McIntosh, 1934.

The specimen of *Notocotylus hassalli* from the jumping mouse agrees closely in appearance and measurements with the type specimen from *Microtus*. Like the type, it has the cirrus entirely covered with minute spines. Likewise, it probably has 5 rows of protrusile glands on the ventral surface, but only a portion of 2 rows is visible in the stained condition.

Host—*Zapus hudsonius hudsonius*.

Location—Small Intestine.

Locality—Douglas Lake, Michigan.

Subulura ungulatus sp. nov.

Figs. 1-4

Fourteen specimens of *Subulura ungulatus* were recovered from a jumping mouse that was trapped in Pine County, 13 from the caecum and one from the esophagus. The caecum is probably the normal site of election and the esophagus an abnormal site.

Specific diagnosis. *Subulura:* Large worms with wide cephalic alae; head large and rounded; lips indistinct. Three bi-lobed teeth around the base of the buccal capsule. The ventral lobe of the central tooth is rounded and attached

to both ventral lobes of the lateral teeth, which are triangular in form. The dorsal lobe of the central tooth is attached to the lateral tooth on the side where the excretory pore occurs. Esophagus 1.36 to 1.45 mm. long by 144 to 160μ wide just anterior to the esophageal bulb, which is 208-240μ in diameter. Nerve ring 284-304μ from the anterior end; excretory pore 464 to 500μ from the anterior end.

Male 15 to 16 mm. long by .43 mm. wide near the middle of the body. Tail curved into a "U"; 4 pairs of preanal papillae; the most anterior pair lies on a level with the center of the preanal sucker. Two pairs of postanal papillae together and immediately posterior to the anus. Preanal sucker 160μ long and situated 480μ from the anus. Anus 284μ from the tip of the tail. Two slender subequal spicules .94 mm. long by 32μ wide at the anterior end; gubernaculum 168μ long by 16μ wide.

Female 18 mm. long by .54 mm wide in the region of the esophageal bulb. Vulva near the middle of the body; two uteri; the posterior loop of the uterus usually extends almost to the level of the anus. Anus .84 mm. from the tip of the tail. The tail averages 150μ in width throughout most of its length, but becomes cone-shaped near the end. Eggs subspherical averaging 55.8μ long by 46.5μ wide; embryonated eggs when ready for deposition average 73.7μ long by 58μ wide.

Host—*Zapus hudsonius hudsonius.*

Location—Caecum.

Locality—Hinckley, Minnesota.

Spiruracerca Zapi gen. nov., sp. nov.

Figs. 5-9

The jumping mouse which harbored 14 specimens of *Subulura ungulatus* also contained 27 specimens of *Spiruracera zapi,* most of them in the stomach, a few in the small intestine, and one in the left lobe of the lung. This nematode has in addition to its own characteristics, characteristics of the genera *Spirura* and *Spirocerca;* and for that reason these generic names were combined to form the new generic name *Spiruracerca,* which is suggested for this nematode.

Generic diagnosis. *Spirurinae:* Mouth hexagonal surrounded by 6 masses of dense parenchymatous tissue. Prominent ventral hump or boss present. Two small trilobed lips. Anterior portion of the body much thinner than the posterior. Spicules slightly alate and unequal; gubernaculum present. Ten pairs of preanal papillae; sometimes an eleventh unpaired lateral papilla which is the most anterior papilla; an unpaired papilla just anterior to the anus; 6 pairs of postanal papillae. Vulva two-thirds the length of the worm from the anterior end. Tail of the female ends in a knob.

Specific diagnosis. *Spiruracerca:* Large worms with the anterior part of the body slender, becoming thicker behind the ventral boss 1.90 to 2.35 mm. from the anterior end. Mouth hexagonal, supported by 6 masses of dense parenchymatous tissue. Cuticle with many fine transverse striations. The esophagus

runs straight until it approaches the ventral boss where it generally becomes much convoluted, and continues to bend in and out until it joins the intestine about 5 to 6 mm. from the anterior end. The intestine below its juncture with the esophagus is usually much convoluted. Esophagus of the male more convoluted than that of the female. Nerve ring 300μ from the anterior end; excretory pore 370μ in the male and 440μ in the famile from the anterior end.

Male 21 mm. long by 338μ wide across the ventral boss. Ten pairs of pedunculate preanal papillae, sometimes 10 pairs plus one extra lateral papilla which is the most anterior papilla; an unpaired papilla anterior to the anus; 6 pairs of postanal papillae. Spicules alate and unequal; the longer 768 to 800μ long by 16μ wide, the shorter 269μ long by 28μ wide. Gubernaculum "V" shaped, 48μ long by 8μ wide. Caudal alae about 1.2 mm. long by 72μ wide. Anus about 282μ from the posterior end.

Female 30 mm. long by about 500μ wide across the ventral boss. Vulva 11.7 mm. from the posterior end; two uteri. Posterior end of the body conical, ending in a knob. Anus about 507μ from the tip of the tail. Eggs subspherical 40μ long by 28μ wide; contain coiled embryos when deposited.

Host—*Zapus hudsonius hudsonius.*

Location—Stomach and small intestine.

Locality—Hinckley, Minnesota.

Parasites of Peromyscus leucopus noveboracensis
Larval Cestode

A larval cestode was removed from the right lobe of the lung of a white-footed mouse that was trapped in St. Paul, Minnesota on January 14, 1937. When the cestode was placed in saline solution, it moved by contracting and expanding its body. The larva is 1.2 mm. long by 292μ wide across the scolex; it gradually diminishes in size to 220μ at the posterior end. The invaginated rostellum bears a double circle of 48 hooks, 24 in each circle. The hooks of the outer circle are 42μ long; the hooks of the inner circle are 52μ long. Each hook has a single small root. The suckers, four in number, are 112μ long by 56μ wide.

Syphacia Samorodini sp. nov.

Figs. 10-12

Forty-four specimens of the nematode, *Syphacia samorodini,* were removed from the digestive tract of P. *l. noveboracensis.* Adults of both sexes were taken from the caecum and the small intestine; females and larvae were removed from the large intestine, and males and larvae from the stomach.

Specific diagnosis. *Syphacia:* Small white worms; the sexes very dissimilar in size and appearance. Head small; 3 small lips. Esophagus short; esophageal bulb nearly spherical. Excretory pore in the female about 320μ from the anterior end; nerve ring about 120μ from the anterior end. Three mamelons, the posterior one always longer than either the first or second mamelon.

Male .5 to .7 mm. long by 72μ wide. The width of the body is rather uniform from the anterior end to the region of the third mamelon, where it becomes narrower. Esophagus plus the bulb 124 to 175μ long; esophagus 28μ wide. Bulb 36 to 42μ in diameter. Narrow cervical alae; cuticle coarsely striated transversely. Three mushroom-shaped mamelons which extend 20μ beyond the cuticle. First and second mamelons 31 to 42μ long; third mamelon 29 to 56μ long, and always longer than the first or second mamelon. Spicule 58 to 68μ long by 2μ wide; gubernaculum 27 to 31μ long by 3.8μ wide. Anus 40μ from the posterior end of the body; tail narow and hook-shaped.

Female 2.7 to 3.4 mm. long by 160 to 192μ wide. Esophagus plus the bulb 320 to 352μ long; esophagus 45μ wide; bulb 70 to 75μ in diameter. Narrow, short cervicle alae present. Excretory pore 320μ from the anterior end; nerve ring 116 to 120μ from the anterior end. Vulva 424 to 480μ from the anterior end. Vagina extends laterally or laterally and anteriorly from the vulva for about 96μ. Anus 576 to 648μ from the tip of the long slender tail. Eggs 86 to 96μ long by 25 to 27μ wide, averaging 91.3 by 26.4μ.

Hosts—*Peromyscus leucopus noveboracensis* and *Peromyscus maniculatus gracilis*.

Location—Small intestine and caecum.

Localities—St. Paul, Minnesota and Hinckley, Minnesota.

Parasites of Peromyscus maniculatus gracilis

Prochoanotaenia Peromysci sp. nov.

Figs. 13-15

Four of 21 specimens of *P. m. gracilis*, collected in Pine County in 1936, were infested with the cestode *Prochoanotaenia peromysci*. The infestations varied from one to 36 worms and averaged 15 worms per mouse. There was definite evidence that the cestodes were producing pathologic conditions, which took the form of erosion and thickening of the intestinal wall. The thickenings were readily visible on the external surface of the intestine.

Generic diagnosis. Genital pores irregularly alternating in two's and three's. Genital ducts passing below the longitudinal excretory vessels. Testes numerous, 20 to 25, post-ovarial. Uterus unstable, replaced by egg capsules, each containing a single egg. Ovary divided into 2 main branches, each consisting of 4 to 6 lobes.

Scolex. About 330μ long by 254 wide; suckers on the dorsal and ventral surface, 82 to 92μ in diameter. Armature consists of a single circle of 22 to 23 fine hooks, each with a single root. The hooks averaged 32μ in length. Rostellum in its extended condition is 133μ long; it is retractable into a "V" shaped pouch 224 to 232μ long by 72μ wide.

General anatomy of strobila. Length of gravid segments about 845μ, width almost the same. Mature but non-gravid segments about 500μ long by 425μ wide. Neck proglottides about 85μ long by 170μ wide. Entire worm not over 4.5 cm. long.

Male reproductive system. Testes in mature segments 24 to 28μ in diameter, spherical or oval in shape; 20 to 25 in each segment, all postovarial. Vas deferens runs anteriorly in a fairly straight course from the ovary to the cirrus pouch, passing ventrad to the excretory vessels. Cirrus pouch clavate running obliquely into the segment for 120μ.

In mature seegments the genital pores open slightly less than one-quarter the length of the segment from the anterior end.

Female reproductive system. Ovary consists of two main branches; the smaller of these lies laterad to the vas deferens on the poral side of the segment; it consists of four lobes. The larger of the two main branches lies laterad to the uterus on the aporal side of the segment; it is made up of 5 to 6 principal lobes. The two main ovarian branches are connected by a narrow bridge-like portion of the ovary; they form a rough semicircle around the circular shell gland and the oblong vitelline gland. The ovary under the low power of the microscope has the appearance of a bunch of grapes. Uterus lies anterior to the shell gland and dorsal to the ovary in mature but non-gravid segments; in gravid segments it breaks down into egg capsules. The vagina, running below the lateral excretory vessels, has the form of an arched tube 12μ wide, lying along the vas deferens. Eggs subspherical averaging 53.6μ long by 43μ wide. Outer shell thin, a thick layer of hyaline material surrounds the inner shell and embryo which is 34 by 20μ.

Host—*Peromyscus maniculatus gracilis*.

Location—Small intestine.

Locality—Hinckley, Minnesota.

Hymenolepis sp.

Cestodes of the genus *Hymenolepis* were recovered from Canadian deer mice that were trapped in Pine County during the summer of 1937. It is quite evident that they belong in this genus, but the poor condition of the material does not warrant specific determination.

Host—*Peromyscus maniculatus gracilis*.

Location—Small intestine.

Locality—Pine County, Minnesota.

Aspiculuris americana sp. nov.

Figs. 16-18

Specific diagnosis. *Aspiculuris:* Three simple lips surrounding a triangular mouth. Esophagus club-shaped, thinnest immediately anterior to the elongate bulb. Cuticle of the head inflated. Cervical alae terminate in a recurved margin a short distance below the level of the esophageal bulb. Cuticle transversely striated. Tail of the male slender and pointed.

Male 2.25 to 2.46 mm. long. Esophagus plus the bulb 288μ long; esophagus 29μ wide. Esophageal bulb 112.5μ long by 48.5μ wide at the base and 31μ wide at the anterior end. Cervical alae recurved, extending 122μ below the base of the esophageal bulb. Tail slender and pointed; a single pair of caudal

alae. Papillae, 4 pairs: one pair immediately anterior to the anus, 3 pairs postanal; the most caudal pair 53.7μ from the anus. Anus 240μ from the posterior end.

Female 3.17 to 3.88 mm. long. Esophagus plus the bulb 381 to 408μ long, esophagus 28μ wide. Esophageal bulb 64μ wide at the base and 43μ wide at the anterior end. Cervical alae recurved, extending 120 to 160μ below the base of the esophageal bulb. Nerve ring 217μ from the anterior end. Vulva opens 1.25 to 1.45 mm. from the anterior end. Uterus extends posterior to the anus, well toward the tip of the tail. Anus 656 to 741μ from the posterior end. Eggs 76 to 83μ long by 27 to 35μ wide.

Hosts—*Peromyscus maniculatus gracilis* and *Peromyscus leucopus noveboracensis.*

Location—Caecum and large intestine.

Localities—Hinckley, Minnesota and St. Paul, Minnesota.

Moniliformis sp.

Three specimens of *Moniliformis sp.* were removed from a Canadian deer mouse that was trapped in Pine County in 1936. In 1937 three more specimens of *Moniliformis sp.* were obtained from the same host species in the same locality. The reproductive organs cannot be made out with certainty in any of the specimens, but the anterior end with the exception of the hooks on the proboscis is clearly defined. The pseudosegmentation is very prominent. One description is given for both sexes. Length 35 to 70 mm. by .75 mm. wide beyond the middle of the body. Neck 256 to 480μ long by 29 to 48μ in width. Proboscis .69 to 1.24 mm. long by 72μ wide; depth of the proboscis pouch .69 to .83 mm. by .25 mm. wide at the base. Lemnisci 4.1 to 7 mm. long by 64 to 80μ wide; large nuclei present.

Host—*Peromyscus maniculatus gracilis.*

Location—Small intestine.

Locality—Hinckley, Minnesota.

Parasites of Microtus pennsylvanicus pennsylvanicus

Andrya sp.

A short broad cestode was removed from the caecum of *Microtus,* and a fragment of the same species from the caecum of the red-backed mouse *(Clethrionomys gapperi g.)* These cestodes are in poor condition, but they appear to belong to the genus *Andrya* and the family *Anoplocephalidae.*

Hosts—*Microtus pennsylvanicus p.* and *Clethrionomys gapperi g.*

Location—Caecum.

Locality—Anoka County, Minnesota.

Andrya sp.

This specimen of *Andrya* is very different from the short broad specimen from Minnesota mice. It is about 9 cm. long and it has irregularly alternating

genital pores. It appears to lack a prostate gland, and the lateral excretory ducts are not greatly developed. It is hoped that more material can be obtained shortly so that it may be adequately described.

Host—*Microtus pennsylvanicus p.*

Location—Small intestine.

Locality—Douglas Lake, Michigan.

Taenia taeniaeformis

On November the 26, 1936, 3 specimens of *Microtus* were taken in the sand dune area of southern Anoka County. One of these, a male, contained a large liver cyst from which a larva of *Taenia taeniaeformis* was removed.

Due to the ever-increasing number of feral house cats, which harbor the adult form of *Taenia taeniaeformis,* the cystic stage may be expected to occur with increasing regularity in the various species of native mice. This, of course, implies that an increase of primary hosts, especially among mustelid mammals and the lynx, will also occur.

Syphacia Obvelata

The nematode, *Syphacia obvelata,* was found in the caeca of 9 of 18 meadow mice. The infestations varied from one to 54 worms, and averaged 18 worms per mouse. No males were recovered.

A Host Catalogue of Helminth Parasites of Native North American Mice

Clethrionomys gapperi g.—Red-backed Mouse.
CESTODA: *Andrya primordialis* Douthitt, (1), (4).
**Andrya* sp.
NEMATODA: *Syphacia obvelata* (Rudolphi, 1802). (5).

Clethrionomys gapperi galei—Gale Red-backed Mouse.
CESTODA: *Andrya primordialis* Douthitt, 1915. (1), (4).

Clethrionomys sp.—Red-backed Mouse.
CESTODA: *Paranoplocephala infrequens* (Douthitt, 1915). (1), (4).

Microtus ochrogaster—Prairie Meadow Mouse.
NEMATODA: *Longistriata carolinensis* Dikmans, 1935. (3).

Microtus pennsylvanicus modestus—Sawatch Meadow Mouse.
CESTODA: *Andrya?* sp. (4).

Microtus pennsylvanicus p.—Eastern Meadow Mouse.
TREMATODA: *Alaria mustelae* Bosma, 1931, (metacercaria) (experimental). (2).
Mediogonimus ovalicus Woodhead and Malewitz, 1936. (21).
Monostomum sp. (19).
Notocotylus hassalli McIntosh and McIntosh, 1934. (11).
Notocotylus quinqueseriale Barker and Laughlin, 1915. (7).
Schistosomatium douthitti (Cort, 1915). (16).
CESTODA: **Andrya* sp.—**Andrya* sp.
**Taenia taeniaeformis* (Batsch, 1786) (larva).

---

* For a discussion see the present paper.

NEMATODA: *Heligomosomum* sp. (14).
Longistriata dalrympei Dikmans, 1935. (3).
Nematospira turgida Walton, 1923.[1] (20).
Oxyuris sp. (19).
**Syphacia obvelata* (Rudolphi, 1802).

Onychomys leucogaster—Grasshopper Mouse.
NEMATODA: *Syphacia obvelata* (Rudolphi, 1802). (5).

Peromyscus gossypinus g.—Cotton Mouse.
TREMATODA: *Scaphiostomum pancreaticum* McIntosh, 1934. (12).
CESTODA: *Diphyllobothrium* sp. (plerocercoid). (13).

Peromyscus leucopus l.—White-footed Mouse.
TREMATODA: *Brachylaemus peromysci* Reynolds, 1938. (17).
Entosiphonus thompsoni Sinitsin, 1931. (6).
NEMATODA: *Rictularia coloradensis* Hall, 1916. (6).
Syphacia peromysci Harkema, 1936 (6).

Peromyscus leucopus noveboracensis—Northern White-footed Mouse.
TREMATODA: *Alariae mustelae* Bosma, 1931 (metacercaria). (2).
Entosophonus thompsoni Sinitsin, 1931. (9).
Fasciola hepatica Linnaeus, 1758, (experimental). (10).
CESTODA: *"Larval Cestode."—*Taenia* sp. (larva). (14).
NEMATODA: **Aspiculuris americana.*—**Syphacia samorodini.*

Peromyscus maniculatus gracilis—Long-tailed Deer Mouse.
CESTODA: *Hymenolepis* sp.—**Prochoanotaenia peromysci.*
NEMATODA: **Aspiculuris americana.*—**Syphacia samorodini.*
ACANTHOCEPHALA: **Moniliformis* sp.

Peromyscus maniculatus nebracensis—Nebraska Deer Mouse.
NEMATODA: *Longistriata carolinensis* Dikmans, 1935. (3).

Peromyscus maniculatus—Long-tailed Deer Mouse.
CESTODA: *Cladotaenia* sp. (larva). (8).
NEMATODA: *Nippostrongylus muris* (Yokogawa, 1920) (experimental). (15).

Peromyscus nasutus—Long-nosed White-footed Mouse.
NEMATODA: *Syphacia obvelata* (Rudolphi, 1802). (5).

Pitymus pinetorum p.—Pine Mouse.
CESTODA: *Taenia* sp. (larva). (14).
NEMATODA: *Oxyuris* sp. (19).

Synaptomys cooperi c.—Cooper Lemming Mouse.
CESTODA: *Andrya* sp. (14).—*Andrya* sp. (14).

"Wild Mouse"
NEMATODA: *Sincosta aberrans* Roe, 1929. (18).

Zapus hudsonius h.—Hudson Bay Jumping Mouse.
TREMATODA: **Notocotylus hassalli* McIntosh and McIntosh, 1934. (11).
NEMATODA: **Spiruracerca zapi.*—**Subulura ungulatus.*

---

[1] Walton originally recorded the host as *Microtus arvalis* but has since indicated that it should be *Microtus pennsylvanicus.*

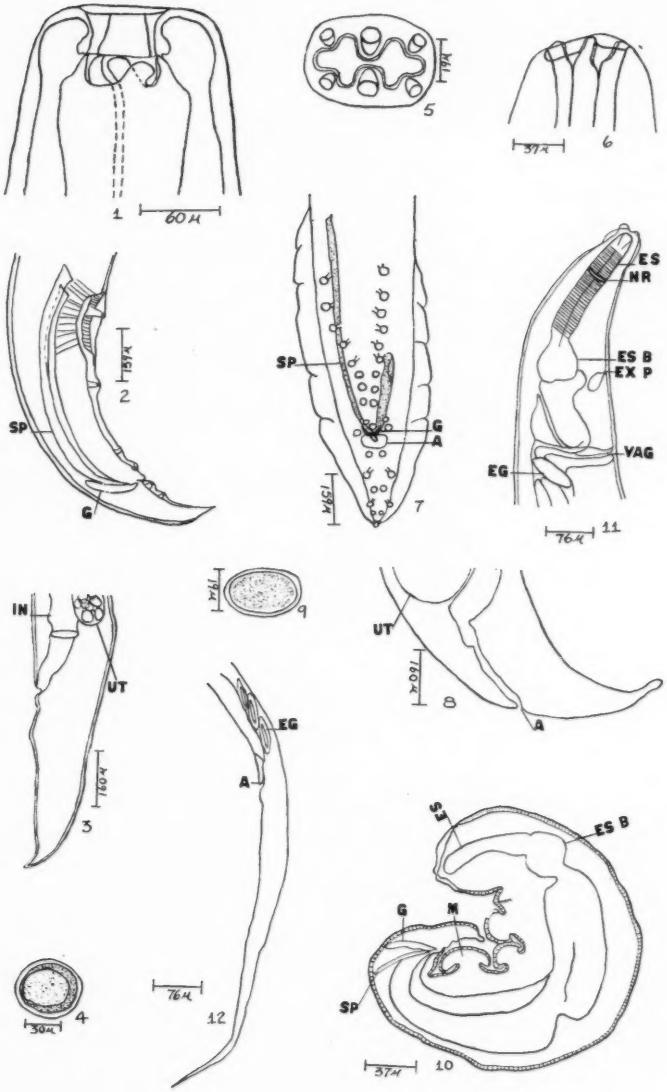
ABBREVIATIONS USED

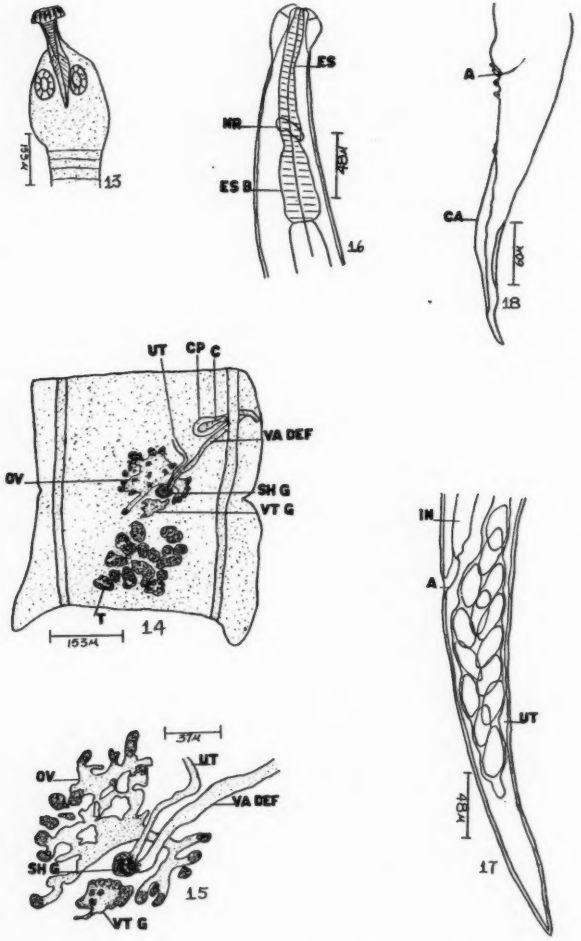
A—anus	IN—intestine
C—cirrus	M—mamelon
CA—caudal alae	NR—nerve ring
CP—cirrus pouch	OV—ovary
EG—egg	SR—seminal recepticle
ES—esophagus	SV—seminal vesicle
ES B—esophageal bulb	T—testes
EX P—excretory pore	UT—uterus
EX V—excretory vessel	VA DEF—vas deferns
G—gubernaculum	VAG—vagina

Figs. 1-4. *Subulura ungulatus*: Fig. 1. Male anterior end ventral view. Fig. 2. Male posterior aend lateral view. Fig. 3. Female posterior end lateral view. Fig. 4. Egg.

Figs. 5-9. *Spiruracerca zapi:* Fig. 5. Head end face view. Fig. 6. Head lateral view. Fig. 7. Male posterior end ventral view. Fig. 8. Female posterior end lateral view. Fig. 9. Egg.

Figs. 10-12. *Syphacia samorodini:* Fig. 10. Adult male entire. Fig. 11. Female anterior end lateral view. Fig. 12. Female posterior end lateral view.


1
60μ
5
19μ
6
37μ
2
152μ
SP
G
SP
G
A
7
152μ
ES
NR
ES B
EX P
VAG
EG
11
76μ
IN
UT
160μ
3
9
19μ
UT
160μ
8
A
EG
A
76μ
12
4
30μ
ES
ES B
G
M
SP
37μ
10



Figs. 13-15. *Prochoanotaenia peromysci:* Fig. 13. Scolex. Fig. 14. Mature proglottid. Fig. 15. Female reproductive system enlarged.

Figs. 16-18. *Aspiculuris americana:* Fig. 16. Female anterior end lateral view. Fig. 17. Female posterior end lateral view. Fig. 18. Male posterior end lateral view.

REFERENCES

(1) Baer, J. G. 1927—Monographie des Cestodes de la famille des *Anoplocephalidae*. Bull. Biol. France et Belg., Suppl., **10**:241 pp.

(2) Bosma, N. J. 1934—The life history of the Trematode, *Alaria mustelae* Bosma, 1931. Trans. Amer. Micros. Soc. **53**:116-153.

(3) Dickmans, G. 1935—The nematodes of the genus *Longistriata* in rodents. Jour. Wash. Acad. Sci. **25**:72-81.

(4) Douthitt, H. 1915—Studies on the cestode family *Anoplocephalidae*. Ill. Biol. Monog. **1**:1-96.

(5) Hall, M. C. 1916—Nematode parasites of mammals of the orders Rodentia, Lagamorpha, and Hyracoidae. Proc. U. S. Nat. Mus. **50**:1-258.

(6) Harkema, R. 1936—The parasites of some North Carolina rodents. Ecological Monographs **6**:151-232.

(7) Harrh, E. G. 1922—North America monostomes, primarily from fresh water hosts. Ill. Biol. Monog. **7**:1-106.

(8) Jellison, Wm. L. Correspondence to the author, April, 1938.

(9) Krull, W. H. 1933—The white-footed mouse, *Peromyscus leucopus noveboracensis*, a new host for *Entosiphonus thompsoni* Sinitsin, 1931; Brachylaemidae. Jour. Parasit. **20**:98.

(10) ———1933—Infections of the white-footed mouse, *Peromyscus leucopus noveboracensis*, with *Fasciola hepatica* Linn. Jour. Parasit. **20**:99.

(11) McIntosh, A. and G. E. McIntosh. 1934—A new trematode, *Notocotylus hassalli* n. sp. (Notocoiylidae) from a meadow mouse. Proc. Helminthol. Soc. Wash. **1**:36-37.

(12) ———1935—New host records of parasites. Proc. Helminthol. Soc. Wash. **2**:80.

(13) ———1937—New host records for *Diphyllobothrium mansonoides* Mueller, 1935. Jour. Parasit. **23**:313-315.

(14) Penner, L. R. Unpublished data on mice parasites.

(15) Porter, D. A. 1935—*Nippostrongylus muris* in the deer mouse, *Peromyscus maniculatus*. Jour. Parasit. **21**:314.

(16) Price, H. F. 1931—Life history of *Schistosomatium douthitti* (Cort). Amer. Jour. Hyg. **13**:685-727.

(17) Reynolds, Bruce D. 1938.—*Brachylaemus peromysci* N. SP. (Trematoda) from the deer mouse. Jour. Parasit. **24**:245-248.

(18) Roe, G. C. 1929—A new nematode, *Sincosta aberrans*, new genus and new species from a rodent. Proc. U. S. Nat. Mus. **75**:1-3.

(19) Stiles, C. W. and A. Hassall. 1894—A preliminary catalogue of the parasites contained in the collection of the U. S. Bureau of Animal Industry, U. S. Army Med. Mus., Biol. Dept. of the Univ. of Penn., and in collections Stiles and Hassall. Vet. Mag. Phila. **1894**:245-253, and 331-354.

(20) Walton, A. C. 1923—Some new and little known nematodes. Jour. Parasit. **10**:59-70.

(21) Woodhead, A. E. and H. Malewitz. 1936—*Mediogonimus ovalacus*, N. G., N. Sp. Jour. Parasit. **22**:273-275.

Dept. of Zoology,
University of Minnesota,
Minneapolis, Minnesota.

Ectoparasitic Trematodes of Puget Sound Fishes*
Acanthocotyle

Kelshaw Bonham and John E. Guberlet

Studies on the monogenetic trematode fauna of Puget Sound fishes have revealed some interesting facts. Here is a field which has been neglected except for a few short publications indicating the presence of certain of the trematodes. At present very little is known concerning the occurrence, distribution, morphology, development, or the various relationships of this fauna of the Pacific Coast. The present observations made on the parasite fauna of Puget Sound fishes have extended over a period of many years during which the occurrence of two species of *Acanthocotyle* has been noted on three species of skates.

These trematodes were tentatively named *A. pacifica* and *A. pugetensis* by Guberlet (1936). The former occurs on the body surfaces of *Raja binoculata* Girard, *R. stellulata* Jordan and Gilbert, and *R. rhina* Jordan and Gilbert, while the latter parasitizes the gills of *Raja binoculata* Girard. It is hoped that the present account is the first of a series of forthcoming publications representing a survey of the ectoparasitic trematodes of Puget Sound fishes.

The observations in this contribution are confined to the genus *Acanthocotyle* Monticelli (1888) of the family Monocotylidae Taschenberg (1879) and the subfamily Monocotylinae Fuhrmann (1928). Price (1936), in a preliminary note, mentioned the erection of a new family Acanthocotylidae for the genus but the complete report is not available. Studies on other families and genera of monogenetic trematodes will appear in the near future. For purposes of classification the system of Fuhrmann (1928) seemed to be most convenient and best adapted to present needs.

Review of Literature

The genus *Acanthocotyle* was established by Monticelli in 1888, for a species *A. lobiancoi* Mont. from the skin of *Raja clavata* in Naples. He augmented it in 1890 by the addition of two new species, and in 1899 summarized his work on *Acanthocotyle* giving specific diagnoses of *A. lobiancoi* Mont. (1888), *A. elegans* Mont. (1890), and *A. oligoterus* Mont. (1899).

Goto (1900) was the second writer to deal with the genus contributing *A. verrilli* Goto, based upon a single specimen. Scott in 1902 reported *A. monticelli* Scott from *Raja clavata*, saying that Monticelli informed him that this is a new species. In 1906, Willem described *A. branchialis* Willem from a European ray.

---

* Contribution from the Departments of Zoology and Oceanography of the University of Washington, Seattle. This is the eighth of a series of publications on the parasites of Puget Sound fishes by John E. Guberlet and his students.

MacCallum was the next to record species under the name *Acanthocotyle*. In four papers he described three species, *A. bothi* MacCallum (1913 and 1917) from *Bothus maculatus*, *A. raiae* MacCallum (1916) on *Raia erinacea*, and *A. squatinae* MacCallum (1921) on *Squatina squatina*, no one of which actually belongs to the genus *Acanthocotyle*, and so, need not be considered further here.

Manter (1926) reported a single specimen of *A. verrilli* Goto (1900) from *Raia erinacea* on the coast of Maine.

The accompanying table shows the principal known characters of the various species as set forth in the literature including some information obtainable solely from the illustrations.

Acanthocotyle pacifica sp. nov.

(Figs. 1-7)

SPECIFIC DIAGNOSIS

In this diagnosis the numerical characteristics of the holotype are given, immediately followed by the extremes of variation, if any, observed in paratypes.

Acanthocotyle Monticelli (1888). Body 4.9 (3.0-5.7) x 1.6 (1.0-1.7) mm. exclusive of haptor, with constriction at level of pharynx. Greatest diameter of haptor less than width of body. Haptor 1.4 (0.9-1.4) mm. in diameter, with 44 (40-47) radiating rows of hooks on ventral surface. Total number of hooks on adult haptor 392 (280-410). Larval haptor (adhesive disk of Monticelli) situated ventrally upon, and at some distance from the posterior edge of, posterior haptor proper, bearing 14 peripheral and 2 central, claw-like hooks. Testes 59 (34-68). Male orifice slightly to right of mid-ventral line just behind level of intestinal bifurcation and armed with spine shaped like head of spear. Vas deferens encircling right digestive crus, with a series of three swellings called seminal vesicles. Two prostate reservoirs opening at male pore. Uterine pore surrounded by swelling at right shoulder of body at level of male pore. Vagina lacking. Stalked eggs (not present in holotype) 430-520 x 65-80 micra with distal, swollen portion 300-380 micra long; stalks 130-140 micra in length.

Hosts: *Raja binoculata* Girard, *R. rhina* Jordan and Gilbert, and *R. stellulata* Jordan and Gilbert.

Habitat: Body Surface.

Locality: Puget Sound region.

Type: U. S. N. M. Holotype No. 9199. Paratypes No. 9200.

Paratypes in collections of writers.

This species of trematode has been found on the dorsal and ventral surfaces of *Raja binoculata* Girard, *R. stellulata* Jordan and Gilbert and *R. rhina* Jordan and Gilbert in about equal degrees of infestation.

Although measurements of the holotype are recorded in the specific diagnosis, only the average, followed by the extremes in parentheses, is given here.

The accompanying table shows the principal known characters of the various species as set forth in the literature including some information obtainable solely from the illustrations.

Species	Host & Habitat	Locality	Approx. Size, m.m.	No. of Specimens*	No. of Larval Hooks	*Large Haptor* No. of Radii	*Large Haptor* No. of Hooks	Birth Pore	No. of Testes	Vagina
A. lobiancoi Monticelli 1888	*Raja clavata* Dorsal skin	Naples	3–6	Several	15	20	211	Left	36	Present
A. elegans Mont. 1890	*Raja clavata* Dorsal skin	Naples	2–4	Several	15	20	139	Left	27	Present
A. oligoterus Mont. 1899	*Raja clavata* Ventral skin	Naples	1.5–2.5	Several	15	20	149	Left	22	Present
A. Verrilli Goto 1900	"A Skate" skin	Cape Cod	4x 1.5	1	20+	34	397	Right	37	?
(ditto) Manter's specimen 1926	*Raia erinacea* Body region?	Maine Coast	4.5x 1	1	14 +2	32	293	Right	52	Present
A. monticelli Scott 1902	*Raja clavata* Gills	North Sea	6.5x 1.2	1	14 +2	20	260±	?	28	?
A. branchialis Willem 1906	"Raie bouclée" Gill mucus	Belgian Coast	5.5x 1.5	10	14 +2	20	226	Right	20-30?	Not visible
A. pacifica n. sp.	*Raja binoculata*, *R. stellulata*, and *R. rhina*, skin	Puget Sound	6x 1.5	20	14 +2	40–47	280–410	Right	57	Lacking
A. pugetensis n. sp.	*Raja binoculata* Gills	Puget Sound	1.5x 0.4	12	14 +2	20	220	Left	7–9	Lacking

* No. of specimens means the number used in describing the species.

An elongate body 4.2 (3.0-5.7) x 1.4 (1.0-1.7) mm., exclusive of haptor, narrows posteriorly to a pedicel by which it attaches to the spine-studded, saucer-like posterior haptor whose diameter, 1.2 (0.9-1.4) mm., is less than the body width. At the level of the posterior end of the pharynx there is a more or less pronounced constriction or neck marking off the head region from the body proper. A conspicuous swelling at the right shoulder indicates the position of the uterine pore, the sole female opening observed in this species. Ventrally and slightly to the right of the median line, at the level of the uterine pore is located the male pore whose presence is marked by a spine, shaped somewhat like the head of a spear. Two anterior suckers are situated at the front of the head, each supplied by a conspicuous group of anterior glands.

The organs of attachment consist of two anterior suckers, about 0.3 mm. long by 0.2 mm. wide, and the posterior haptor, approximately 1.2 mm. in diameter, including its component larval haptor averaging 0.1 mm. in diameter.

Monticelli (1899) considered the anterior suckers to be true suckers and, in fact, his figures show them as flat, shallow cups with the free edges turned inward. Goto (1900) believed them to be merely outwardly opening ducts from the anterior glands whose secretion is thus of an adhesive nature. Manter (1926) supports Monticelli's interpretation. Observations on living worms in the present study show so conclusively that these organs are true suckers that there can be no question in regard to their function, although the anterior glands do secrete an adhesive fluid.

The haptor, which in this paper refers to the posterior haptor, resembles a rubber suction disk whose inner surface bears many peculiar spines. Morphologically, the haptor is ventral although it may be turned dorsally or posteriorly, and is capable of twisting through as much as 180 degrees as in the holotype. Its ventral position is clearly indicated by the presence of a minute accessory disk, the larval haptor, near the posterior border when the large haptor is turned face downward.

Approximately 43 (40-47) radiating rows of spines or hooks lie with their bases embedded in the ventral surface of the haptor. The rows are easily counted peripherally, but toward the center of the disk it is often difficult to determine to which row a spine belongs. The total number of hooks has been observed to vary between 280 and 410. Strangely enough it is not necessarily the individual with the largest number of rows that possesses the greatest number of hooks. There is little correlation in this regard. For example, a specimen with only 40 rows of hooks possessed the maximum total number, 410. A row contains from 4 to 13 hooks, the minimum number being found in the two rows at the sides of the larval haptor. That the small "adhesive disc" of Monticelli is actually the haptor of the larva is beyond question, since it is clearly visible in well developed, shelled embryos. Proceeding outward and forward around the disk, one finds an increasing number of hooks in a row until the maximum number is encountered at the sides of the disk, to decrease again to about 8 in the anterior part of the large haptor opposite the larval haptor.

All of the spines of the adult haptor are hollow. Peripheral spines (Fig. 6) are elongate, 60 x 25 micra, broadest at the bases, and are embedded parallel to the surface within the tissue of the haptor nearly as far as the distal portion where there is a flange-like blade projecting ventrally at right angles to the shaft of the spine. The spines (Figs. 4, 5) nearer the center are shorter, 45 x 38 micra, and have broader embedded bases from which arise tapering, protruding shafts bearing distally thin, striated flanges that are crescent-shaped in surface view. Between the periphery and the center there is an intergradation of these two types of spines.

The vestigial larval haptor is a small pad of tissue attached by a narrow base to the ventral surface of the large haptor near the posterior margin of the latter but not at the very edge as in the three species described by Monticelli and in *Acanthocotyle pugetensis* described in the present paper. Fourteen peripheral, and two central spines (Figs. 2, 3) are present on those specimens where they could be definitely counted. There seems to be no structural difference between them. The spines are borne on straight, chitinous supports, 20-30 micra long, embedded in the larval haptor. The hook is a curved, stout claw about 8-10 micra long lying mainly at right angles to the support. The "merletto" of Monticelli, here referred to as the marginal membrane, is an insignificant band of transparent tissue around the edge of the haptor. It is best seen in cross sections.

Simplicity marks the digestive tract of *Acanthocotyle*. A conspicuous pharynx at the level of the neck opens to the ventral surface slightly beyond its anterior edge by way of the mouth. The digestive tract bifurcates immediately behind the pharynx without the intervention of an oesophagus. Two simple, digestive crura devoid of outpocketings proceed directly as far as the posterior end of the vitellaria where they terminate separately.

The most obvious feature of the excretory system in *Acanthocotyle* is the pair of large excretory vesicles lying immediately anterior to the vitellaria, opening dorso laterally by narrow tubes which proceed obliquely forward and outward from the vesicles. Irregular tortuous excretory canals, ventral to the intestine, can be seen in sections.

The brain lying antero-dorsally to the pharynx gives off a large pair of ventral and smaller lateral nerve trunks, best discerned in sectioned material.

Male Reproductive System.—Globular testes about 0.1-0.2 mm. in diameter number from 34 to 68 with an average of about 57, and are intercaecal and post-ovarian in position. Sperm originating in the testes is transferred from the anterior testicular region through an extemely fine vas deferens which encircles the right intestinal caecum starting dorsally from the testes, passing laterally over the caecum, ventrally along the lateral margin of the caecum, and finally medially on the ventral side of the caecum, up to the seminal vesicle.

The seminal vesicle consists of three portions, a proximal, posterior area (SV_1) indefinitely circumscribed and connected by a short neck to a middle, clearly bounded portion (SV_2) which is spherical in shape. Starting with the duct connecting these two portions, the sperm tract has a definite, avidly

staining wall. From the middle portion a duct which enlarges into a swollen, crescentic, distal vesicle (SV_3), proceeds forward and terminates anteriorly at the male pore. No cirrus is distinguishable, but there is a spine, probably an intromittent spine, shaped like the head of a spear, which sometimes protrudes slightly from the pore. The male pore is situated about 0.1 mm. behind the bifurcation of the intestine on the ventral surface of the body approximately 0.1 mm. to the right of the median line.

Two swollen, spindle-shaped, colloid-filled vesicles terminate at the genital pore. These are the prostrate reservoirs and are about equal in size to the crescentic, anterior seminal vesicle. Their principal portions lie ventrally to this distal seminal vesicle, but their posterior portions pass laterally to this male duct and cross each other dorsally to the vas deferens. Shortly posterior to this point there ceases to be a lumen in the structure and the colloidal contents change to a more intensely staining, eosinophlic substance which originates in the fine efferent ducts of two extensive fields of unicellular prostate glands situated laterally to the intestinal caeca and vitellaria. The one prostate reservoir whose swollen portion lies to the right receives the ducts from the left side of the body—its mate those from the right. Posterior and ventral to the prostate reservoirs and ventral to the seminal vesicle is the uterus.

Female Reproductive Organs.—The ovoid ovary, about 0.3 x 0.2 mm. in size, is slightly larger and more deeply staining than the testes. It lies antero-ventrally to the foremost testis and to the left of the median line.

The vitellaria (Fig. 1) consist of a pair of elongated bodies composed of numerous lobules and occupy positions lateral to the intestinal crura. They transmit their contents ventro medially into longitudinal yolk ducts situated along the ventro-lateral edges of the intestinal crura. The anterior ends of the yolk ducts curve medially and fuse to form a yolk reservoir, which passes posteriorly about 0.1 mm. where it unites with the oviduct as the latter proceeds to the oötype. Originating at the dorso-median edge of the ovary at the level of about the middle of the ovary, the oviduct passes ventrally, and then branches anteriorly and posteriorly. The anterior branch communicates with the terminal portion of the yolk reservoir while the posterior branch forms a blind pocket, perhaps a vestigial seminal receptacle, about 50 micra long. The proximal portion of the oviduct and its anterior branch are distended with sperm, thus forming a functional seminal receptacle. From the union of the oviduct with the yolk reservoir the canal passes dorsally to the base of the oötype where it is surrounded by a corona of deeply-staining, eosinophilic, efferent ducts arising from giant unicellular shell glands, about eleven in number, situated as a wreath around the canal which connects the base of the oötype with the posterior end of the yolk reservoir. From the shell gland corona, the oötype passes directly antero-ventrally, about 0.5 mm., where it opens into the uterus at a point ventral to, and slightly to the left of, the middle seminal vesicle. Starting at the anterior end of the oötype the uterus proceeds obliquely forward to the uterine pore situated near the right margin of the body at the same level as the male pore. The uterus passes ventrally to the right intestinal caecum and then bends dorsally before proceeding as the metraterm (Monticelli 1899) to the dorsal side of the right shoulder of the

body. A large, irregular, sucker-like swelling, the metratermal sheath of Monticelli, surrounds the metraterm.

Eggs are of the usual stalked form with a swollen distal portion measuring 300-380 micra long by 65-80 micra in diameter. Stalks about 130-140 micra long increase the total lengths of the eggs to 420-530 micra. These stalks serve to attach the eggs together at their bases in bundles of half a dozen or more which may be deposited in clusters, or frequently may adhere to the body at the uterine pore.

Within some of the eggs showing advanced development the 16 hooks of the larval haptor, arranged in a circle, may be seen (Fig. 7). This arrangement of spines in the embryo differs not only from that of the vestigial larval haptor of the adults, of both *A. pacifica* and *A. pugetensis* n. sp., but also from the condition found in the embryo of *A. pugetensis* where 14 of the spines are situated peripherally in a circle surrounding the other two, centrally located hooks.

Comparison with other Acanthocotyle

Acanthocotyle pacifica n. sp. differs principally from previously described species in lacking a vagina, and in the large number (40-47) of rows of hooks on the haptor. The species most closely resembling it is *A. verrilli* Goto (1900) with 34 rows taken from a skate on the Atlantic Coast of North America. This species was reported again in 1926 by Manter who recorded 32 rows of hooks. Literature at hand shows that in no other described species does the number of rows exceed 20.

Acanthocotyle pugetensis sp. nov.

(Figs. 8-10)

Some specimens of the Big Skate, *Raja binoculata* Girard, infested with *Acanthocotyle pacifica* also harbored upon their gills another species of this genus. This second species, designated as *A. pugetensis* n. sp., is so small that it can be observed with the naked eye only by careful scrutiny. Upon the basis of a careful search under the dissecting microscope of one or two of the large holobranchs from each host specimen, and a less intensive examination of the rest of the gills, it was estimated that the parasites occur in numbers ranging from one or two to a thousand or more on a single skate.

Specific Diagnosis

The numerical characteristics of the holotype are given, immediately followed by the extremes of variation, if any, observed in the paratypes.

Acanthocotyle Monticelli (1888). Body 1.2 (0.75-1.3) x 0.33 (0.23-0.43) mm. exclusive of haptor which is larger than body width, measuring 0.43 (0.30-0.53) mm. in diameter and possesses 20 radiating rows of hooks and the larval haptor. Total number of large hooks 227 (208-227). Larval haptor situated dorsally near posterior edge of main haptor, and bears 14 peripheral and 2 central claw-like hooks. Testes 7-9. Male orifice median.

ventral to intestinal bifurcation. Vas deferens encircling left digestive crus. Two prostate reservoirs opening at male pore. Uterine sac present containing numerous eggs, in gravid individuals. Uterine pore on left side at level of male pore. Vagina lacking. Egg, about 160 (120-170) x 50 (34-70) micra, ovoid, with long slender filament; eggs retained in uterine sac until embryos are well developed.

Host: *Raja binoculata* Girard.

Habitat: Gill filaments.

Locality: Puget Sound region.

Type U. S. N. M. Holotype no. 9197. Paratypes no. 9198.

Paratypes in collections of writers.

The form of the body of *Acanthocotyle pugetensis* is similar to that of *A. lobiancoi* Monticelli except that it is much smaller. There is no constriction in the region of the pharynx as in *A. pacifica* from Puget Sound. Body size, exclusive of haptor, averages 1.0 (0.75-1.3) x 0.33 (0.23-0.43) mm. The posterior haptoral disk is wider than the broadest part of the body in contrast to *A. pacifica*.

The anterior suckers, measuring about 70 x 50 micra, appear much as those figured by Goto (1900) for *A. verrilli* Goto and also like those of *A. pacifica*. Eosinophilic granular tracts extend posteriorly to a mass of large cells, the "anterior glands" of Monticelli, lying laterally to the pharynx and bifurcation of the intestine.

The posterior haptor is almost circular in outline averaging 0.43 (0.30-0.53) mm. in diameter and bears dorsally at its median posterior edge the small larval haptor, 90 micra in diameter, provided with hooks. The large haptor possesses 20 radiating rows of hooks shaped as in *A. pacifica*. Each row consists of from 4 to 14 hooks while the total number is about 220. The peripheral spines are larger than those more medially situated. Fourteen hooklets are imbedded in the periphery and two more occupy a central position in the larval haptor.

Small depressions beside the median edges of the anterior suckers are present. They seem to be the efferent ducts of unicellular glands scattered between the anterior suckers, since they are filled with material which is sometimes slightly exuding from their mouths. They are definitely not tentacles such as Monticelli (1899) described for *Acanthocotyle lobiancoi, A. oligoterus*, and *A. elegans*. In all probability these are accessory adhesive ducts.

Giant secretory cells lie ventrally to the posterior testes and communicate by ducts through the peduncle of the haptor to its ventral surface where in one sectioned specimen hematoxylin-stained droplets may be seen strewn among the spines just beneath the cuticle. It is undoubtedly an adhesive system which supplies a sticky secretion to the ventral surface of the haptor.

A narrow, elongate buccal cavity opens postero-dorsally into the enlarged lumen of the pharynx. At the posterior edge of the pharynx unicellular salivary glands discharge their contents into the digestive tract. Immediately upon leaving the pharynx, the tube branches into the two intestinal crura which pass

posteriorly without any outpocketings almost to the haptoral attachment where their posterior ends approach each other but do not unite. The crura are lined by irregular prominences, a few of which are nucleated and look definitely like cells.

An excretory pore opens to the surface dorso-laterally on either side of the body at about one third of the body length from the anterior end. The exact course of the excretory canals was not traced, but longitudinal canals are definitely present ventral to the crura.

The brain lies arched across the anterior end of the pharynx and gives off anteriorly nerve fibers grouped mainly into two pairs of bundles, one pair median and close together and the other located farther apart. One strand is dorsal to each of the groups of unicellular glands supplying the large anterior haptors. Both of these pairs break up to ramify through out the anterior portion of the body. The brain sends out posteriorly a conspicuous pair of nerves which drop to a position ventral to the intestinal crura and the longitudinal excretory canals.

Male Reproductive System.—There are usually 7-9 rounded testes about 50-80 micra in diameter located between the caeca in the posterior half of the body. On the left side at the anterior end of the testicular region, the vas deferens arises ventrally. It passes antero-dorsally beside the median edge of the intestine of the left side, crosses the dorsal surface of the intestinal crus to its lateral edge, drops ventrally beside the lateral edge of the crus, and turns medially again in a position ventral to the crus. Its spiral course thus far has carried it constantly forward to a position some distance directly anterior to its origin. It then passes dorsally between the intestinal crus and the left edge of the uterine sac. Upon reaching the dorsal body musculature it crosses diagonally forward and toward the right, dorsally to the uterine sac. It then dips ventrally beside the median edge of the right crus and passes anteriorly and ventrally beside the latter, curving medially to open at the male genital pore which is ventral to the bifurcation of the intestine. The terminal portion of the vas deferens, the ejaculatory duct, passes between the two prostate reservoirs.

The posterior relationships of the prostate reservoirs cannot be discerned so well in this species as in the larger *A. pacifica,* but their finely granular, eosinophilic contents seem to be contributed by small prostate cells, lying close to the body musculature laterally in much the same position as in *A. pacifica,* but of less significant proportions.

Female Organs.—The spheroidal ovary, 70-100 micra in diameter, is located in the center of the body in specimens which do not contain many eggs, but is forced back to a position about two-thirds of the way from the anterior end in those specimens which contain many eggs within the uterine pouch. From the left side of the ovary arises the oviduct which passes ventrally, then anteriorly a short distance where it gives off the seminal receptacle and continues dorsally to unite with the oötype which is dorsally situated between the uterine pouch and the ovary. The oötype is a conspicuous duct

and displays marked internal protuberances. Its shape conforms to the curvature of the posterior end of the uterine pouch, and from its right, distal end arises the uterus which follows forward alongside the uterine pouch to about the middle of the right side of the latter where it enters. The large uterine pouch is somewhat oval in outline excepting at the left anterior end where it tapers out to the minute uterine pore located at the level of the intestinal bifurcation. As many as 34 eggs may be contained within the pouch or sac which may be swollen to a size one-third the length of the worm by three-quarters of its width.

The ovoid eggs vary in size, but average about 150 x 50 micra, and possess long slender filaments. They are so arranged in the uterine sac that the filaments lie at a point near the entrance of the uterus proper. The filaments are entangled here in a mass such that it seems impossible for the eggs to be deposited excepting all at once. In specimens whose uterine pouches contain only a few eggs, these are not far advanced, but in those with 20 or more eggs, each developing embryo within already displays the larval haptor oriented toward the stalked end of the egg with its 16 hooks arranged as in the vestigial larval haptor of the parent, 14 peripherally and 2 centrally. Fifteen peripheral hooks seem to be present in some of the embryos.

The yolk glands occupy a position lateral to the intestinal crura from the middle of the body back almost to the ends of the crura. A collecting yolk duct follows the ventro-median edge of the vitelline area of each side just ventrally to the intestine as in *A. pacifica*. The vitelline lobules discharge their contents into this duct whose anterior end turns postero-medially to follow, tightly pressed against the posterior end of the swollen uterine sac, around to the oviduct-complex, always being ventral to the other ducts. A vagina is lacking.

Comparison with other Acanthocotyle

Acanthocotyle pugetensis n. sp. differs from previously described species in its small size (1.0 x 0.3 mm.), small number of testes (7-9), in lacking a vagina, and in possessing a large uterine pouch. *A. oligoterus* Mont. (1899), 1.5-2.5 mm. long, most closely approaches its small size, but possesses approximately 22 testes and has only 15 hooks in the larval haptor. No other species has fewer than 22 testes unless it be *A. monticelli* Willem (1906) for which the number is not given, but whose indistinct illustration suggests the testes to be 20-30 in number.

Summary

Two new species of *Acanthocotyle* are described and figured from Puget Sound Rajidae. The literature of this genus is summarized in a table of characteristics. Important features hitherto undescribed are the presence of large, paired, prostate reservoirs opening at the male pore, the lack of a vagina, the vas deferens' encircling the digestive crus, and the presence of an intromittent spine at the male pore of *A. pacifica* n. sp. It is pointed out that the "adhesive disc" of Monticelli is the vestigial, larval haptor.

ABBREVIATIONS

AG—anterior gland
AS—anterior sucker
DPR—Dorsal prostate reservoir
E—excretory vesicle
HLH—hook of larval haptor
HO—hook
I—intestine
LH—larval haptor
LPR—left prostate reservoir
M—marginal membrane
Mo—mouth
MP—male pore
O—oötype
Ov—ovary
P—pharynx
PG—Prostate gland
PH—posterior haptor
RPR—right prostate reservoir
SaG—salivary gland
SG—shell gland
SV_1—proximal portion of seminal vesicle
SV_2—middle portion of seminal vesicle
SV_3—distal portion of seminal vesicle
SR—seminal receptacle
T—testis
U—uterus
UP—uterine pore
US—uterine sac
VD—vas deferens
Vi—vitellarium
ViD—vitelline duct
VPR—ventral prostate reservoir

PLATE 1

All figures made with the aid of a camera or camera lucida.

Acanthocotyle pacifica n. sp.

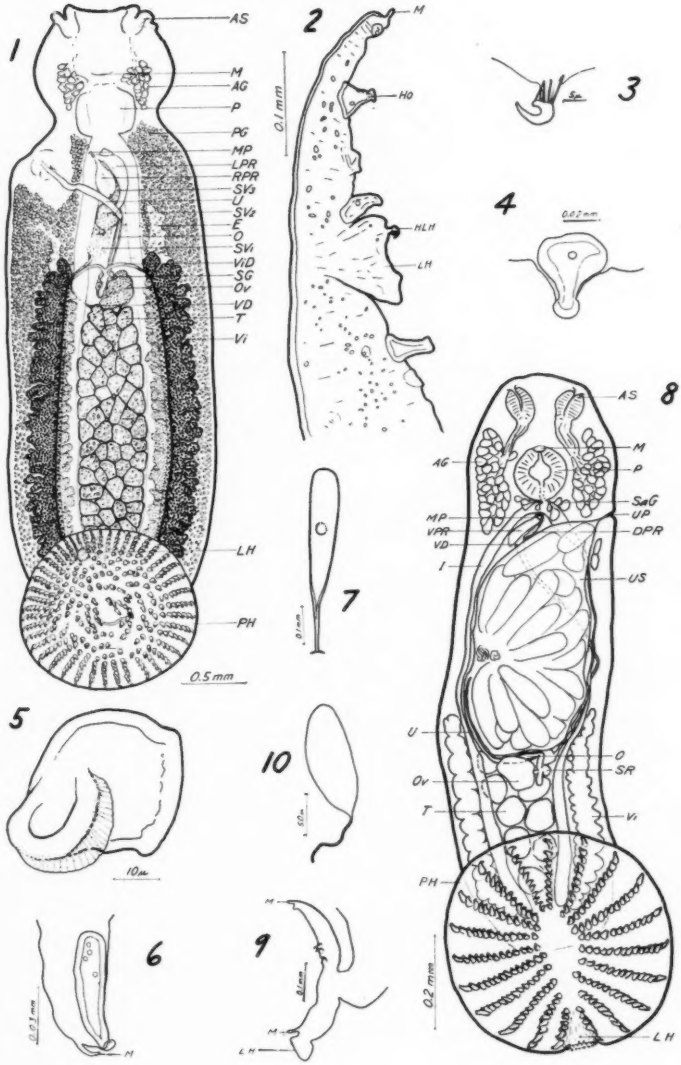
FIGURES

1. Holotype, ventral view. x21.
2. Section through peripheral portion of haptor to show larval haptor. x170.
3. Peripheral hook of larval haptor. x700.
4. Haptoral spine from middle of a row, showing the broad base and tapering shaft embedded in the haptor. x310.
5. Spine from middle portion of haptor. Arrow points toward center of haptor. x750.
6. Section of edge of haptor showing marginal membrane and a long, embedded, peripheral spine with its flange protruding ventrally. x 310.
7. Egg from a cluster of eleven. All 16 of the larval hooks are arranged in a circle resembling a nucleus within the egg shell. x60.

Acanthocotyle pugetensis n. sp. (Figs. 8-10).

8. Holotype, ventral view. x80.
9. Outline of sagittal section of haptor to show position of larval haptor. x60.
10. Shelled egg prematurely expelled by pressure from cover slip. x130.

PLATE I


1
AS
M
AG
P
PG
MP
LPR
RPR
SV3
U
SV2
E
O
SV1
ViD
SG
Ov
VD
T
Vi
LH
PH
0.5mm
2
M
Ho
0.1mm
HLH
LH
3
4
0.02mm
5
10μ
6
0.01mm
M
7
0.1mm
8
AS
M
AG
P
SaG
MP
UP
VPR
DPR
VD
I
US
U
O
Ov
SR
T
Vi
PH
0.2mm
LH
9
M
0.1mm
M
LH
10
0.1mm

REFERENCES

FUHRMANN, O. 1928—Zweite Klasse des Cladus Plathelminthes: Trematoda. In "Handbuch der Zoologie" von Kükenthal und Krumbach, Berlin und Leipzig, **2**:1-140.

GOTO, S. 1900—Notes on some exotic species of ectoparasitic trematodes. Jour. Coll. Sci. Tokyo **12**:263-295.

GUBERLET, JOHN E. 1936—Trematodes ectoparasitos de los peces de las costas del Pacifico. Anales Inst. Biol. **7**(4):457-467.

MACCALLUM, G. A. 1913—Notes on four trematode parasites of marine fishes. Centrbl. Bakt. **70**:407-416.

———1916—Some new species of parasitic trematodes of marine fishes. Zoopathologica **1**:1-38.

———1917—Some new forms of parasitic worms. Zoopathologica **1**:43-75.

———1921—Studies in helminthology. Zoopathologica **1**:137-284.

MANTER, H. W. 1926—Some North American fish trematodes. Ill. Biol. Monographs **10**:1-138.

MONTICELLI, FR. SAV. 1888—Saggio di una morfologia dei trematodi. Thesis, R. Univ. Naples, pp. 1-128.

———1890—Note elmintologiche: I—Nota preliminare sul genere *Acanthocotyle*. Boll. Soc. Natur. Napoli **4**:189-208.

———1899—Il genere *Acanthocotyle*. Arch. Parasit. **2**:75-120.

PRICE, EMMETT W. 1936—North American Monogenetic Trematodes. George Washington University Bulletin, Washington, D. C. Summaries of Doctoral Thesis. 1934-1936. 4 pages.

SCOTT, T. 1902—Notes on some parasites of fishes. Report Fish. Board Scotland, 20th. **3**:288-302.

WILLEM, V. 1906—Deux trematodes nouveaux pour la faune Belge. Bull. Acad. roy. Belgique, Bruxelles, pp. 599-612.

Studies on Gill Trematodes from Oklahoma Fishes*

Aaron Seamster

Introduction

This investigation which deals with ectoparasitic flukes from Oklahoma fishes was begun in October, 1937. Problems involving technical laboratory procedures requisite for permanent mounts, the validity of the genus *Haplocleidus* Mueller, 1937, control methods, and new distributional records of hosts are considered.

Host specimens, which constitute one hundred thirty-seven fish belonging to the families Centrarchidae and Ameiuridae, were collected from streams and ponds in the vicinity of Stillwater, Oklahoma. After identification the hosts were either preserved by freezing or kept in laboratory aquaria pending experimentation. Parasites were collected and preserved according to the method described by Mizelle (1938b).

In order to determine combinations of fixatives and stains for optimal structural differentiation, five fixatives and five stains were employed. Twenty-five preparations were treated with each fixative and twenty-five (five to each fixer) with each stain.

The genus *Haplocleidus* Mueller, 1937, was split off the genus *Onchocleidus* Mueller, 1936, to include forms which exhibit a marked discrepancy in size of the dorsal and ventral anchors. This genus is considered invalid since a gradation of anchor lengths ranging from those characteristic of the genus *Cleidodiscus* Mueller, 1936, to those of *Haplocleidus* Mueller, 1937, has been observed in *Cleidodiscus pricei* Mueller, 1936.

Experiments on control measures employing chlorine, advocated by Laird (1927) and Laird and Embody (1931) (by use of Zonite), were performed in laboratory aquaria. Chlorinated water prepared by the local water plant was found reliable because of its constant chlorine content and availability.

This work is the first of its kind to be undertaken in the state of Oklahoma. Many new distribution records are reported. A preliminary report of the investigation was presented in December, 1937, at a meeting of the Oklahoma Academy of Science (Seamster, 1938).

Nomenclature for structural parts is used as proposed by Price (1934), Mueller (1936), and Mizelle (1936).

The author wishes to express his thanks and appreciation to Dr. John D. Mizelle of the Department of Zoology, Oklahoma Agricultural and Mechanical College, for his advice and direction of the problem.

---

* A contribution from the Zoological Laboratory of the Oklahoma Agricultural and Mechanical College.

Systematics

Johnston and Tiegs (1922) in Australia first gave comprehensive consideration to ectoparasitic flukes of the superfamily Gyrodactyloidea. Specific taxonomic work on this group of parasites in North America began with the description of *Gyrodactylus fairporti* Van Cleave, 1921, from *Cyprinus carpio* and *Ameiurus melas*. Later, Van Cleave and Mueller (1932) described *Ancyrocephalus aculeatus* from *Stizostedion vitreum* and Mueller and Van Cleave (1932) described *Gyrodactylus cylindriformis* from *Umbra limi* and *Dactylogyrus extensus* from *Cyprinus carpio*. Mueller (1934, 1936a, 1936b, 1937, 1938) described nine new genera, namely, *Cleidodiscus, Urocleidus, Onchocleidus, Leptocleidus, Tetracleidus, Aristocleidus, Haplocleidus, Pterocleidus* and *Actinocleidus* and many new species belonging to these and other genera of the Dactylogyridae and Gyrodactylidae. In 1934 Mueller assigned *Ancyrocephalus aculeatus* to the genus *Urocleidus* and in 1936 he restricted *Ancyrocephalus* to permanently include marine species and retained it provisionally for fresh-water forms of uncertain generic standing. Mizelle (1936, 1937, 1938a, 1938b) described several new species of Dactylogyrinae and Tetraonchinae from Illinois fishes. Price (1937) described *Gyrodactylus gurleyi* from goldfish ("Japanese fan tail") and reviewed the superfamily Gyrodactyloidea. Mizelle and Hughes (1938) reduced the nine Muellerian genera to the following: *Cleidodiscus, Urocleidus,* and *Actinocleidus*. This paper deals mainly with North American fresh-water Tetraonchinae.

Previous to 1933 the Tetraonchinae were included in the family Gyrodactylidae Cobbold, 1877. Bychowsky (1933) created the family Dactylogyridae which now includes the following sub-families: Dactylogyrinae Bychowsky, 1933; Tetraonchinae Monticelli, 1903; Diplectaninae Monticelli, 1903; and Bothitrematinae Price, 1936. The following is a classification of the North American fresh-water Tetraonchinae with a list of species.

Phylum.—PLATYHELMINTHES
Class.—TREMATODA
Order.—MONOGENEA
Suborder.—MONOPISTHOCOTYLEA
Superfamily.—GYRODACTYLOIDEA
Family.—DACTYLOGYRIDAE
Subfamily.—TETRAONCHINAE

Genus.—*Tetraonchus* (Wagener, 1857) Diesing, 1858.

Species.—1. *Tetraonchus monenteron* Wagener, 1857. Syn. *Dactylogyrus monenteron* Wagener, 1857; *Gyrodactylus cochlea* Wedl, 1857; and *Monocoelium monenteron* (Wagener, 1857) Wegener, 1910.

2. *Tetraonchus alaskensis* Price, 1937.

Genus.—*Murraytrema* Price, 1937.

Species.—1. *Murraytrema copulata* Mueller, 1938.

Genus.—*Cleidodiscus* Mueller, 1934. (*Leptocleidus* Mueller, 1936, in part)

Species.—1. *Cleidodiscus robustus* Mueller, 1934. Syn. *Cleidodiscus incisor* Mizelle, 1936.

2. *Cleidodiscus megalonchus* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Leptocleidus megalonchus* Mueller, 1936.
3. *Cleidodiscus capax* Mizelle, 1936.
4. *Cleidodiscus longus* Mizelle, 1936.
5. *Cleidodiscus uniformis* Mizelle, 1936.
6. *Cleidodiscus vancleavei* Mizelle, 1936. Syn. *Onchocleidus formosus* Mueller, 1936, and *Cleidodiscus formosus* (Mueller, 1936) Price, 1937.
7. *Cleidodiscus bedardi* Mizelle, 1936.
8. *Cleidodiscus floridanus* Mueller, 1936.
9. *Cleidodiscus pricei* Mueller, 1936.
10. *Cleidodiscus nematocirrus* Mueller, 1937.
11. *Cleidodiscus mirabilis* Mueller, 1937.
12. *Cleidodiscus stentor* Mueller, 1937.
13. *Cleidodiscus brachus* Mueller, 1938.
14. *Cleidodiscus alatus* Mueller, 1938.
15. *Cleidodiscus diversus* Mizelle, 1938.

Genus.—*Urocleidus* Mueller, 1934. Syn. *Onchocleidus* Mueller, 1936, in part; *Tetracleidus* Mueller, 1936, in part; *Aristocleidus* Mueller, 1936, in part; *Haplocleidus* Mueller, 1937, in part; *Pterocleidus* Mueller, 1937, in part.

Species.—1. *Urocleidus aculeatus* (Van Cleave and Mueller, 1932) Mueller, 1934. Syn. *Ancyrocephalus aculeatus* Van Cleave and Mueller, 1932.
2. *Urocleidus ferox* Mueller, 1934. Syn. *Onchocleidus ferox* (Mueller, 1934) Mueller, 1936.
3. *Urocleidus angularis* Mueller, 1934. Syn. *Ancyrocephalus angularis* (Mueller, 1934) Mueller, 1936.
4. *Urocleidus adspectus* Mueller, 1936.
5. *Urocleidus similis* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus similis* Mueller, 1936.
6. *Urocleidus mimus* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus mimus* Mueller, 1936.
7. *Urocleidus helicis* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus helicis* Mueller, 1936.
8. *Urocleidus acer* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus acer* Mueller, 1936, and *Pterocleidus acer* (Mueller, 1936) Mueller, 1937.
9. *Urocleidus dispar* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus dispar* Mueller, 1936, and *Haplocleidus dispar* (Mueller, 1936) Mueller, 1937.
10. *Urocleidus banghami* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Tetracleidus banghami* Mueller, 1936.
11. *Urocleidus principalis* (Mizelle, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus principalis* Mizelle, 1936, and *Onchocleidus contortus* Mueller, 1937.
12. *Urocleidus interruptus* (Mizelle, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus interruptus* Mizelle, 1936.
13. *Urocleidus mucronatus* (Mizelle, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus mucronatus* Mizelle, 1936.
14. *Urocleidus acuminatus* (Mizelle, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus acuminatus* Mizelle, 1936, and *Pterocleidus acuminatus* (Mizelle, 1936) Mueller, 1937.

15. *Urocleidus distinctus* (Mizelle, 1936) Mizelle and Hughes, 1938. Syn. *Onchocleidus distinctus* Mizelle, 1936.
16. *Urocleidus hastatus* (Mueller, 1936) Mizelle and Hughes, 1938. Syn. *Aristocleidus hastatus* Mueller, 1936.
17. *Urocleidus perdix* (Mueller, 1937) Mizelle and Hughes, 1938. Syn. *Onchocleidus perdix* Mueller, 1937.
18. *Urocleidus spiralis* (Mueller, 1937) Mizelle and Hughes, 1938. Syn. *Onchocleidus spiralis* Mueller, 1937.
19. *Urocleidus affinis* (Mueller, 1937) Mizelle and Hughes, 1938. Syn. *Haplocleidus affinis* Mueller, 1937.
20. *Urocleidus furcatus* (Mueller, 1937) Mizelle and Hughes, 1938. Syn. *Haplocleidus furcatus* Mueller,
21. *Urocleidus biramosus* (Mueller, 1937) Mizelle and Hughes, 1938. Syn. *Pterocleidus biramosus* Mueller, 1937.
22. *Urocleidus malleus* (Mueller, 1938) Mizelle and Hughes, 1938. Syn. *Cleidodiscus malleus* Mueller, 1938.
23. *Urocleidus chautauquaensis* (Mueller, 1938) Mizelle and Hughes, 1938. Syn. *Tetracleidus chautauquaensis* Mueller, 1938; and *Cleidodiscus chautauquaensis* (Mueller, 1938) Mueller, 1938.
24. *Urocleidus umbraensis* Mizelle, 1938.
25. *Urocleidus cyanellus* (Mizelle, 1938) Mizelle and Hughes, 1938. Syn. *Onchocleidus cyanellus* Mizelle, 1938.

Genus.—*Actinocleidus* Mueller, 1937.

Species.—1. *Actinocleidus fusiformis* (Mueller, 1934) Mueller, 1937. Syn. *Cleidodiscus fusiformis* Mueller, 1934.
2. *Actinocleidus oculatus* (Mueller, 1934) Mueller, 1937. Syn. *Cleidodiscus oculatus* Mueller, 1934.
3. *Actinocleidus bursatus* (Mueller, 1936) Mueller, 1937. Syn. *Ancyrocephalus bursatus* Mueller, 1936.
4. *Actinocleidus articularis* (Mizelle, 1936) Mueller, 1937. Syn. *Cleidodiscuss articularis* Mizelle, 1936.
5. *Actinocleidus gracilis* Mueller, 1937.
6. *Actinocleidus maculatus* Mueller, 1937.
6. *Actinocleidus maculatus* Mueller, 1937.
7. *Actinocleidus triangularis* Summers, 1937.
8. *Actinocleidus longus* Mizelle, 1938.
9. *Actinocleidus fergusoni* Mizelle, 1938.

Technical Procedure

Little success in preparing differentially stained mounts of Tetraonchinae has been accomplished. Mizelle (1937) experienced difficulty in obtaining a good differential stain and recommended unstained mounts for accurate study.

In order to discover an optimal fixer-stain combination for these forms a comparative study of fixing and staining procedures was attempted. Five fixers, Gilson's, formalin (ten percent), alcohol (seventy percent), Karpenchenko's, and Bouin's; and five stains, Harris' haemotoxylin, Delafield's haemotoxylin, Heidenhain's haemotoxylin, picrocarmine, and borax carmine were employed.

In order to insure relatively uniform results, preparations of *Cleidodiscus pricei* Mueller, 1936, were used throughout the experiment.

It was observed that the formalin-Heidenhain's haemotoxylin combination produced the best results and that the Bouin's-Harris' haemotoxylin yielded the poorest. The head organs were differentiated by all the stains. Although the ovary was best differentiated by Heidenhain's haemotoxylin, the testis failed to differentiate plainly. Haptoral and copulatory complex parts were usually obscured by the stained surrounding tissues. Karpenchenko's and alcohol (seventy percent) gave the least desirable results as fixers.

It is apparent that unstained preparations are best for study since the essential structures (anchors, hooks, bars, cirrus, and accessory piece), for classification, are obscured by staining.

Validity of the Genus *Haplocleidus* Mueller, 1937

The genus *Onchocleidus* Mueller, 1936, was created to include Tetraonchinae with the following characteristics: "Intestine bifurcate, confluent posteriorly. Ovary anterior to testes, near center of body. Vagina present, on right; small seminal receptacle present. Cirrus a chitinous slender tube, at times with spiral fins, at times coiling. Accessory piece generally absent. Vitellaria from pharynx to posterior end of intestine. Haptor wedge-shaped. Four anchors may or may not be of equal size, with short roots, and long shafts and points. Fourteen marginal hooks. Two supporting bars, not joined, approximately similar in size and shape. . . .

"This genus is distinguished from *Cleidodiscus* and *Urocleidus* in lacking the accessory piece for the cirrus. It is distinguished from the latter in the presence of a vagina, and from the former in having the vagina on the right"* *Onchocleidus* is distinguished from *Leptocleidus* Mueller, 1936, by the presence of a relatively simple cirrus, from *Tetracleidus* Mueller, 1936, by the absence of an accessory piece in the copulatory complex, and from *Aristocleidus* Mueller, 1936, by the possession of dorsal and ventral anchors of similar size and shape. Original members of these genera (except *Aristocleidus*) possess anchors of nearly equal size except *Onchocleidus dispar* Mueller, 1936. In 1937 Mueller named the genus *Haplocleidus* to include *Onchocleidus*-like forms which possess a marked difference in size of dorsal and ventral anchors (dorsals larger); *Pterocleidus* to apply to *Onchocleidus*-like species which have a spur-like projection on each anchor shaft; and *Actinocleidus* to include *Cleidodiscus*-like species with all four anchors on the same side of the haptor and articulate or fused bars. Mizelle and Hughes (1938) recognized the sporadic absence of vaginae in several genera besides *Urocleidus*, the insignificance of spines and spurs on haptoral parts, the presence of an accessory piece in the copulatory complex of nearly all species of *Onchocleidus*, a size and shape discrepancy of the two pairs of anchors in the later described species belonging to genera other than *Haplocleidus* and reduced Mueller's nine genera to three, namely, *Cleidodiscus*, *Urocleidus*, and *Actinocleidus*. Support for suppressing the genus *Haplocleidus* was partially obtained from data presented in this paper.

* Mueller, 1936a.

In addition to the previously recorded *Cleidodiscus pricei* Mueller, 1936, from *Ameirus melas* there was found a *Haplocleidus* form, on this host, with a copulatory complex identical with that of *Cleidodiscus pricei* (Figs. 4 and 5). Examination of a large number of specimens revealed an almost complete gradation of anchor sizes between those of *Cleidodiscus pricei* and the *Haplocleidus*-like form. The cirrus measurements for the two forms were nearly the same (Chart). This difference in size of the two pairs of anchors is interpreted to be a normal variation in this species and lends support to the invalidity of the genus *Haplocleidus* as contended by Mizelle and Hughes (1938).

CHART I.

Structural Variation in *Cleidodiscus pricei* Mueller, 1936.

Specimen	*Dorsal Anchors*	*Ventral Anchors*	*Cirrus*	
1	0.038 mm.	0.032 mm.	0.028 mm.	
2	0.038 mm.	0.032 mm.	0.027 mm.	
3	0.038 mm.	0.033 mm.	0.025 mm.	
4	0.038 mm.	0.033 mm.	0.028 mm.	
5	0.040 mm.	0.033 mm.	0.028 mm.	
6	0.040 mm.	0.033 mm.	0.027 mm.	
7	0.042 mm.	0.033 mm.	0.028 mm.	
8	0.042 mm.	0.033 mm.	0.028 mm.	
9	0.042 mm.	0.033 mm.	0.028 mm.	
10	0.042 mm.	0.033 mm.	0.028 mm.	
11	0.040 mm.	0.035 mm.	0.028 mm.	
12	0.042 mm.	0.037 mm.	0.025 mm.	
13	0.042 mm.	0.037 mm.	0.032 mm.	
14	0.042 mm.	0.038 mm.	0.025 mm.	
15	0.043 mm.	0.038 mm.	0.028 mm.	Av. 0.275 mm.
16	0.049 mm.	0.041 mm.	0.025 mm.	
17	0.051 mm.	0.041 mm.	0.033 mm.	
18	0.053 mm.	0.041 mm.	0.033 mm.	
19	0.054 mm.	0.041 mm.	0.033 mm.	
20	0.054 mm.	0.041 mm.	0.030 mm.	
21	0.056 mm.	0.041 mm.	0.025 mm.	
22	0.058 mm.	0.041 mm.	0.026 mm.	
23	0.058 mm.	0.041 mm.	0.029 mm.	
24	0.058 mm.	0.043 mm.	0.033 mm.	
25	0.058 mm.	0.043 mm.	0.026 mm.	
27	0.056 mm.	0.044 mm.	0.031 mm.	
28	0.056 mm.	0.044 mm.	0.031 mm.	
29	0.054 mm.	0.046 mm.	0.028 mm.	Av. .0297 mm.

Numbers 1-15 inclusive represent typical *Cleidodiscus* forms; numbers 16-29 represent *Haplocleidus*-like forms.

CONTROL EXPERIMENTS

During the early part of the investigation it was observed that fishes kept in laboratory aquaria for more than twenty-four hours prior to examination were negative for gill parasites. Chlorine effects were suspected since this element was known to be present in the local water supply and had been used previously by Laird (1927) and Laird and Embody (1931) (by use ofZonite) to destroy Gyrodactyloidea. The water was tested, using the orthotolodine method, and found to contain 0.1 ppm. of free chlorine.

In order to rule out possible detrimental effects to Gyrodactyloidea by materials in solution, other than chlorine, the following experiment was performed. One fish *(A. melas)* infested with *Cleidodiscus pricei* Mueller, 1936, was placed in chlorine-free distilled water, one in chlorinated distilled water, one in chlorine-free tap water, and one in chlorinated tap water. Chlorine-free distilled water proved more toxic to *C. pricei* than chlorinated distilled water, and the latter was more toxic than chlorinated tap water. Dechlorinated tap water had no effect on this species of parasite. Determination of possible complimentary effects of dissolved salts and chlorine became complicated since the chlorine-free distilled water was more toxic to *C. pricei* than was chlorinated distilled water. Due to lack of time and equipment, determinations of this nature were not attempted. Further experiments were devised to test the interval of exposure necessary to kill Gyrodactyloidea by use of chlorinated tap water.

In each of the following experiments 0.1 ppm. of chlorine in tap water was used as a vermicide. Controls showed that parasites and hosts were unaffected by chlorine free tap water and that that hosts were unaffected by chlorinated tap water. Bullheads and crappies were kept in chlorinated water for periods of two weeks without evident harm. Brownian movement within parasites was used as a criterion of death.

Two bullheads *(A. melas)* infested with *C. pricei* were placed in chlorine solution. At the end of the first hour all parasites on one host were alive. At the end of the second hour eighty-eight percent of the parasites on the second host were dead. Four additional experiments, using the same experimental set up, showed the minimal lethal time of exposure for *C. pricei* to vary from three to six hours. Parasites that died during the shorter intervals were taken from a local pond. Fish harboring parasites that required upper ranges of exposure for lethal effect were taken from a slowly-moving stream (Boomer Creek).

Two black crappies *(Pomoxis sparoides)* infested with *Cleidodiscus vancleavei* Mizelle, 1936, were placed in an aquarium containing chlorinated water. Microscopic examinations were made on each fish at alternate hours. Six, and six and one-half hours, respectively, were required to kill all the gill trematodes present on the two hosts.

There remains much work to be done on control measures utilizing chlorine as a vermicide. Experiments show that dissolved chlorine in small amounts (0.1 ppm.) is lethal to Gyrodactyloidea, but that the time required to kill parasites is variable. The author realizes that these experiments are preliminary in scope but believes them suitable as a basis for further study.

GYRODACTYLOID HOST RECORDS FROM OKLAHOMA

Host: *Helioperca macrochira* (Rafinesque)
Urocleidus mucronatus (Mizelle, 1936) Mizelle and Hughes, 1938.
Actinocleidus fergusoni Mizelle, 1938.
Urocleidus dispar (Mueller, 1936) Mizelle and Hughes, 1938.
Urocleidus acer (Mueller, 1936) Mizelle and Hughes, 1938.

Ictalurus punctatus (Rafinesque)
Cleidodiscus pricei Mueller, 1936.

Ameiurus melas (Rafinesque)
Cleidodiscus pricei Mueller, 1936.
Gyrodactylus elegans von Nordmann, 1832.

Apomotis cyanellus (Rafinesque)
Actinocleidus longus Mizelle, 1938.
Cleidodiscus diversus Mizelle, 1938.
Urocleidus cyanellus (Mizelle, 1938) Mizelle and Hughes, 1938.

Pomoxis annularis (Rafinesque)
Cleidodiscus vancleavei Mizelle, 1936.
Cleidodiscus longus Mizelle, 1936.

Pomoxis sparoides Lacépède
Cleidodiscus vancleavei Mizelle, 1936.

Micropterus dolomieu Lacépède
Urocleidus principalis (Mizelle, 1936) Mizelle and Hughes, 1938.

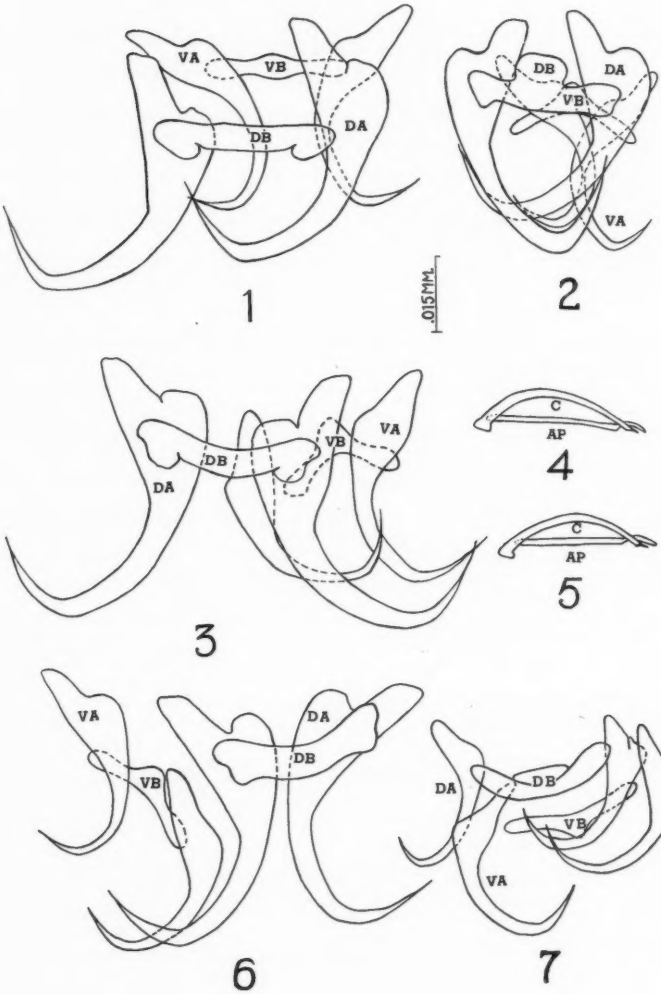
Aplites salmoides (Lacépède)
Actinocleidus fusiformis (Mueller, 1934) Mueller, 1937.

Allotis humilis (Girard)
Urocleidus mucronatus (Mizelle, 1936) Mizelle and Hughes, 1938.
Urocleidus dispar (Mueller, 1936) Mizelle and Hughes, 1938.
Actinocleidus fergusoni Mizelle, 1938.

PLATE 1

Comparative figures of *Cleidodiscus pricei* Mueller, 1936. Figs. 2, 5, and 7 are of typical forms. Figs. 1, 3, 4, and 6 are of the *Haplocleidus* type which show increased size of dorsal anchors. Original anchor size described for this species (Mueller, 1936b) is 0.058 mm. This measurement is the maximum dorsal anchor size recorded in this investigation. For further variation in haptoral and copulatory structures see Mueller, 1936b, plate 57, figs. 12-15.

D.B.—Dorsal Bar
V.B.—Ventral Bar
D.A.—Dorsal Anchor
V.A.—Ventral Anchor
A.P.—Accessory Piece
C.—Cirrus


VA
VB
DA
DB
1
.015MM.
DB
DA
VB
VA
2
DA
DB
VB
VA
3
C
AP
4
C
AP
5
VA
VB
DA
DB
6
DA
DB
VB
VA
7

REFERENCES

BYCHOWSKY, ? ?. 1933—Beitrag zur Kenntnis neuer monogenetischer Fisch-trematoden aus dem Kaspisee nebst einigen Bemerkungen über die Systematik der Monopisthodiscinea Fuhrmann, 1928. Zool. Anz. **105**(½):2-38.

EMBODY, G. C. 1924—Notes on the control of *Gyrodactylus* on trout. Trans. Amer. Fish. Soc. **54**:48-53.

JOHNSTON, T. H. AND O. W. TIEGS. 1922—New gyrodactyloid trematodes from Australian fishes, together with a reclassification of the superfamily Gyrodactyloidea. Proc. Linn. Soc. New South Wales **47**(2):83-131.

LAIRD, J. A. 1927—The use of Zonite in treating gill worms. Trans. Amer. Fish. Soc. **57**:177-179.

LAIRD, J. A. AND G. C. EMBODY. 1931—Controlling the trout gillworm (*Discocotyle salmonis* Schaffer). Ibid. **61**:189-191.

MACCALLUM, G. A. 1915—Some new species of ectoparasitic trematodes. Zoologica **1**(20):395-410.

MIZELLE, J. D. 1936—New species of trematodes from the gills of Illinois fishes. Amer. Midl. Nat. **17**(5):785-806.

———1937—Ectoparasites of the blunt-nosed minnow *(Hyborhynchus notatus)*. Ibid. **18**(4):612-621.

———1938a—New species of monogenetic flukes from Illinois fishes. Ibid. **19**(2):465-470.

———1938b—Comparative studies on trematodes (Gyrodactyloidea) from the gills of North American fresh-water fishes. Ill. Biol. Monographs **17**(1):(in press).

MIZELLE, J. D. AND R. C. HUGHES. 1938—North American fresh-water Tetraonchinae. Amer. Midl. Nat. **20**(2):341-353.

MUELLER, J. F. 1934—(Parasites of Oneida Lake fishes). Part IV. Additional notes parasites of Oneida Lake fishes, including descriptions of new species. Roosevelt Willd Life Annals **3**(4):336-372.

———1936a—Studies on North Americaan Gyrodactyloidea. Trans. Amer. Micros. Soc. **55**(1):55-72.

———1936b—New gyrodactyloid trematodes from North American fishes. Ibid. **55**(4):457-464.

———1937—Further studies on North American Gyrodactyloidea. Amer. Midl. Nat. **18**(2):217-219.

———1938—Additional species of North American Gyrodactyloidea (Trematoda). Ibid. **19**(1):220-235.

MUELLER, J. F. AND H. F. VAN CLEAVE. 1932—Parasites of Oneida Lake fishes. Part II. Descriptions of new species and some general taxonomic considerations, especially concerning the trematode family Heterophyidae. Roosevelt Wild Life Annals **3**(2):79-139.

PRICE, E. W. 1934—A new term for the adhesive organs of trematodes. Proc. Helminth. Soc. Wash. **1**(2):34.

———1937—North American monogenetic trematodes. I. The superfamily Gyrodactyloidea. Jour. Wash. Acad. Sci. **27**(3):114-130, and (4):146-164.

SEAMSTER, A. 1938—Gill trematodes from Oklahoma fishes. Proc. Okla. Acad. Sci. (in press).

SUMMERS, W. A. 1937—A new species of Tetraonchinae from *Lepomis symmetricus*. Jour. Parasitol. **23**(4):432-434.

VAN CLEAVE, H. J. 1921—Notes on two genera of ectoparasitic trematodes from fresh-water fishes. Ibid. **8**(1):33-39.

VAN CLEAVE, H. J. AND J. F. MUELLER. 1932—Parasites of Oneida Lake fishes. Part I. Descriptions of new genera and new species. Roosevelt Wild Life Annals **3**(1):5-71.

A Description of Cercaria raiacauda n. sp.*

Gerald M. Steelman

In the fall of 1937 and the summer of 1938 a number of clams, *Musculium elevatum* (Haldeman), from Boomer Creek near Stillwater, Oklahoma, were examined for trematode larvae. The cercariae of *Gorgodera amplicava* Looss, *Crepidostomum* sp., and a macrocercous form, *Cercaria raiacauda* n. sp., were found. In an examination of about 200 specimens of another clam, *Sphaerium aureum declive* Sterki, from the same locality, none was found to be infected with this form.

Material was studied in both live and preserved states; live specimens yielded results far superior to those obtained from the study of stained material. The use of neutral red as an *intra vitam* stain proved effective in the study of certain anatomical details. Flame cells were studied by the use of urine as described by West (1935); it was found necessary to dilute the urine with about an equal volume of water to prevent too rapid killing of the cercariae. Specimens stained in borax carmine and mounted *in toto* presented a clear view of the primordia of the reproductive organs.

Cercaria raiacauda sp. nov.

Figs. 1 to 6

Description.—Macrocercous cercaria. Tail distinctly subdivided into a somewhat discoidal proximal portion into which body is completely retracted and a slender distal region. Proximal portion comprises median region and a pair of lateral wings. "Cercarial chamber" occupies approximately two-thirds of median region. Posterior to cercarial chamber median region consists of compact parenchyma. Parenchyma of lateral wings very loose. Tail thickest in region of cercarial chamber which appears to bulge slightly on both dorsal and ventral surfaces; wings, thickest adjacent to cercarial chamber, with rounded margins. Each wing bordered anteriorly by a somewhat rigid hyaline, apparently chitinized, sickle-shaped area. Cercarial chamber cone-shaped being widest anteriorly. Forward surface of chamber circular, somewhat arched

* A contribution from the Zoological Laboratory of the Oklahoma Agricultural and Mechanical College, prepared under the direction of R. Chester Hughes.

Dr. E. W. Price of the Zoological Division, Bureau of Animal Industry, United States Department of Agriculture, kindly checked the availability of the name "raiacauda" for a new species of cercaria.

The clams referred to in this paper were identified by Dr. Paul Bartsch of the United States National Museum.

I am especially indebted to the late Dr. D. F. Ssinitzin for having presented us with his last copy of the monograph—Ssinitzin 1905.

anteriorly, projecting slightly anteriad to wings. External opening of cercarial chamber a median ventral longitudinal slit bounded and closed by thick lateral lips. Body of cercaria attached to posterior wall of cercarial chamber. Body curved ventral, with middle region forward and anterior portion directed posteriad. Distal portion of tail, composed of somewhat compact richly nucleated parenchyma, tapers slightly toward abruptly rounded end.

Measurements, length x width in microns, of 10 specimens fixed in hot 70 percent alcohol and mounted in fixative under supported cover glass. Tail, proximal portion 258 (230-288) x 377 (345-410), distal portion 497 (468-540) x 74.8 (72-86), body 314 (288-338) x 77.8 (65-94). Diameter: oral sucker 55.6 (54-58; acetabulum 50.9 (49-53). Stylet 21.3 (19.4-24.6) long.

Sensory papillae: a pair of lateral rows of 15 each distributed somewhat uniformly along entire length of body, the first three and the last three being somewhat closer together than the others; a pair of ventral rows of 5 each, 4 of which are uniformly spaced between oral sucker and acetabulum and ones lightly behind acetabulum; a pair of dorsal rows of 2 each located over oral sucker; 6 radially arranged double papillae around opening of acetabulum, two of these median; 18 about oral sucker arranged in two concentric rings, inner ring having 3 pairs immediately adjacent to mouth, outer ring with 6 pairs—members of the second pair from the front being more centrally located than the others. Bands of sensory hairs around oral sucker and acetabulum; no hairs on sensory papillae. Inner portion of each sucker bearing a wide band of minute quincuncially arranged clavate spines surrounding mouth in oral sucker and a circular bare area in acetabulum. A naked zone between spines and sensory hairs in both suckers.

Mouth small, subterminal; pharynx absent. Esophagus thick-walled with very narrow lumen; bifurcation midway between oral sucker and acetabulum; caeca narrow, sinuous, dorsolateral, extending to end of body. Brain, supra-esophageal commissure, and bases of anterior and posterior nerves plainly visible. Genital primordium, a dorso-median mass of cells behind acetabulum with a thread of cells extending anteriad from it and curving ventrad to terminuate near ventral surface immediately in front of acetabulum, scarcely recognizable in living material.

Excretory bladder large, median, with two lateral collecting tubules at anterior end; excretory pore terminal and slightly dorsal. Bladder surrounded by compact cylindrical mass of "cystogenous gland cells" (Krull, 1935) with their longitudinal axes at right angles to that of bladder. In optical frontal section, a row of about 9 gland cells on either side of bladder, one anterior to lateral collecting tubule and others posterior. Medial half of each cystogenous gland cell coarsely granular, lateral half clear and containing nucleus. Twenty-five pairs of flame cells; 3 pairs anterior to brain, the first ones being near posterior border of oral sucker, 3 pairs uniformly spaced between brain and acetabulum, 6 pairs lateral to acetabulum, and 13 pairs posterior to acetabulum. Positions of flame cells generally closer to lateral edge of body than to median line. No flame cells observed in tail.

Penetration gland cells, 10 pairs at level of bifurcation of esophagus; 6 pairs lateral to caeca and 4 pairs intercaecal; "extracaecal" cells slightly more anteriad and much more responsive to neutral red. Their tubules on either side of body soon become contiguous to form a pair of groups which pass dorsal to brain commissure thence anterolaterad to dorsolateral surface of oral sucker. Dilatations in various positions along length of tubules, especially at level of oral sucker. Tubules enter oral sucker at about one-third its length from the front and curve medioventrad to open into cavity about stylet. Stylet, proximal end rounded, distal end with dorsally-curved ventrally-placed point and a pair of rounded dorsolateral prominences; set almost at right angles to longitudinal axis of body.

Sporocysts.—Length 0.5-2.5 mm.; numerous in gills of all infected clams dissected; elongate, much more so in some than in others, often U-shaped, one end abruptly rounded, the other more or less pointed; birth pore not definitely observed but cercariae were seen to emerge from small end; blunt end attached to gill, smaller end free in gill cavity; containing cercariae in various developmental stages. Encysted metacercariae found inside sporocysts from dead clams; cysts not found in sporocysts from living hosts. Metcercaria similar to cercaria but with lumen of excretory bladder much inflated and the adjacent glandular cells much reduced in size and lacking the stylet now found on the inner surface of the ovoidal cyst.

Behavior.—Cercariae emerge somewhat periodically at intervals of a few hours in numbers of about 15 to 25. There appears to be no relationship between the periodicity and the time of the day or the numbers produced. Cercariae were observed to be expelled from the excurrent siphon of the host. The cercaria is most active immediately after emergence; it swims, progressing tail first, almost directly upward, by rapid lateroventral lashings of the distal portion of the tail. When the cercaria reaches the surface of the water the lashing of its tail ceases and it begins to sink. The longitudinal axis of the proximal portion of the tail is held vertically when swimming and horizontally when resting on the bottom of the container. Activity of the cercaria decreases with age. After remaining in the water for some time, or when placed under cover glass pressure, the fore part of the body is extended from the cercarial chamber and the cercaria may become completely free from the tail which remains sluggishly active for some time. The free cercaria crawls along the bottom of the container by means of the suckers. The shape of the proximal portion of the tail is usually altered when the cercaria detaches itself. The globe shrinks in size and generally becomes misshapen and wrinkled; the cercarial chamber disappears as its side walls press together in the median plane.

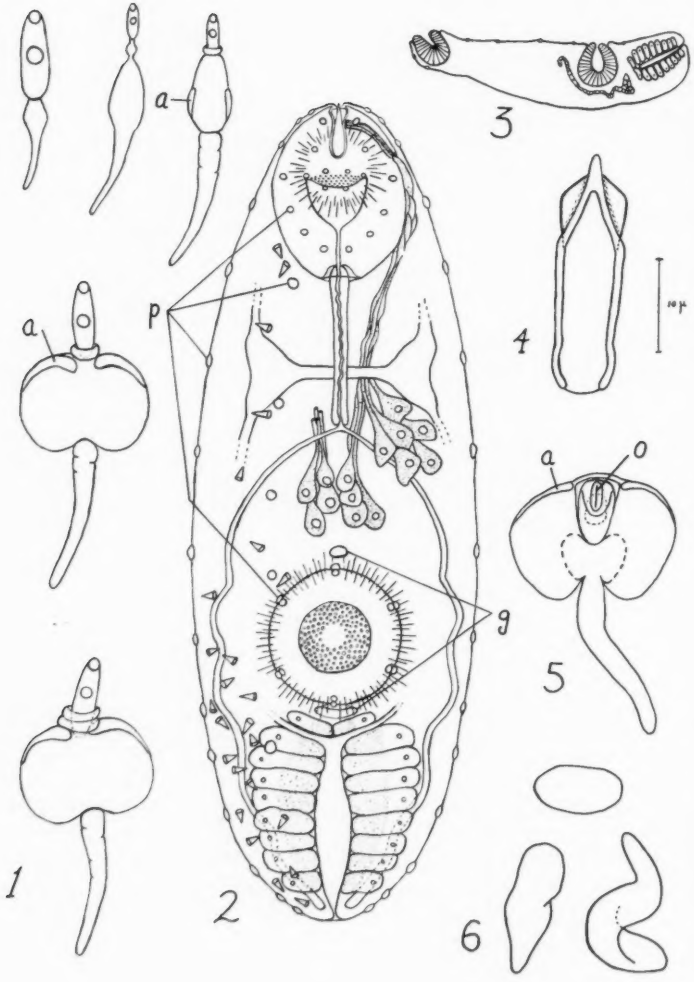
Host.—Musculium elevatum (Haldeman).

Locality.—Boomer Creek near Stillwater, Oklahoma.

Incidence.—Of about 400 clams examined approximately 5 percent were infected.

Type specimens.—Ten decaudated specimens mounted *in toto* in the United States National Museum.

PLATE 1



Discussion

Cercaria raiacauda is a cysticercous form close to the "Gorgodera" and "Gorgoderina" groups of Sewell (1922), recognized as larvae of the family Gorgorderidae Looss 1902. Adult gorgoderid flukes for which the cercariae are presumedly known include the European *Gorgodera loossi* Ssinitzin 1905, *Gorgodera pagenstecheri* Ssinitzin 1905, *Gorgodera varsoviensis* Ssinitzin 1905, *Gorgoderina vitelliloba* (Olsson 1876) Looss 1902, *Phyllodistomum folium* (von Olfers 1816) Braun 1899, and *Phyllodistomum clausii* (Monticelli 1888) mihi [=*Phyllodistomum acceptum* Loos 1901] and the North American *Gorgodera amplicava* Looss 1899. The cercariae of the first four of these were described (originally only for *G. varsoviensis*) by Ssinitzin (1905), according to whom *Cercaria macrocerca* de Filippi 1854 is the larva of *G. vitelliloba*, whereas the forms identified as *C. macrocerca* by Wagener (1857) and Thiry (1860) belong respectively to *G. loossi* and *G. pagenstecheri*. Sewell (1922), however, regarded *C. macrocerca* de Filippi as the larva of *Gorgodera cygnoides* Looss 1894 [=Ssinitzin's *G. loossi*]. The cercaria of *P. folium* described originally as *Distomum duplicatum* von Baer 1827 was redescribed by Reuss (1903). According to Odhner (1911) *P. acceptum* develops from *Cercaria clausii* Monticelli 1888 redescribed by Pintner (1891). Krull (1935) described the cercaria of *G. amplicava*. *Cercaria spaerocerca* and *C. mitocerca* in North America were described as "Gorgoderine" by Miller (1935).

Of these 9 forms the new species is most like the cercaria of *Gorgoderina vitelliloba* in which, according to the figures by Ssinitzin (1905), the penetration gland cells are more numerous and not divided into distinct inter- and extracaecal groups, the "cystogenous gland cells" are smaller and more numerous, the genital primordia are more highly developed, a greater number of sensory papillae occur both on the suckers and on the body, the papillae

PLATE 1

All figures concern *Cercaria raiacauda* n. sp. and, except fig. 2, were drawn with the aid of a camera lucida. All except figs. 3 and 4 were drawn chiefly from living material. Abbreviations: a—hyaline area, p—sensory papillae, g—genital primordium, o—opening of cercarial chamber.

FIGURES

1. Five stages in the development of the cercaria drawn from specimens dissected from sporocysts.
2. Composite study of the anatomy of the body proper—ventral view.
3. Side view of body from stained *in toto* mount—shows genital primordium and excretory bladder.
4. Stylet—ventral view.
5. Fully developed cercaria with body proper retracted within cercarial chamber—ventral view.
6. Three sporocysts showing variations in shape.

on the acetabulum are not double, and the opening of the cercarial chamber is terminal.

The 4 known cercariae of the genus *Gorgodera* differ from the present form in having fewer penertation gland cells which are not divided into distinct extra- and intercaecal groups, more numerous cystogenous gland cells arranged about the excretory bladder in a different manner, the primordia of the reproductive organs more highly developed with (except in *G. amplicava*) testes and ovary represented by separate masses, and a stylet of more complex form.

In the cercaria of *Phyllodistomum folium* the excretory bladder is divided into two distinct parts, the reproductive organs are very highly developed, and the tail is cylindrical, not used in locomotion, without distinct subdivisions, and is all involved in the later formation of an ovoidal cyst enclosing the body of the cercaria. The marine *C. clausii* is unusual in being an oculate colonial ("Rattenkönig") form with only 2 pairs of (penetration?) gland cells and with conspicuous yellow and black pigmentation. If it be true that *C. clausii* is the larva of *P. acceptum* the latter name should be changed to *P. clausii* as indicated above.

Cercaria sphaerocerca lacks the lateral projections of the stylet possessed by *C. raiacauda*, has a smaller diameter ratio of oral sucker to acetabulum, and has the cercarial chamber located anterior to the globe of the tail, the globe being more elongate. *Cercaria mitocerca* has no stylet, the body is not withdrawn into a cavity in the tail, the genital primordia are much further developed, and the distal portion of the tail is very long and "thread-like."

REFERENCES

KRULL, W. H. 1935—Studies on the life history of a frog bladder fluke, *Gorgodera amplicava* Looss, 1899. Pap. Mich. Acad. Sci., Arts and Let. **20**:697-710.

MILLER, E. L. 1935—Studies on North American cercariae. Jour. Parasit. **21**:244-254.

ODHNER, T. 1911—Zum natürlichen System der digenen Trematoden IV. Die Familie Azygiidae n. Fam. Zool. Anz. **38**:513-531.

PINTNER, T. 1891—Ueber *Cercaria clausii* Monticelli. Arb. Zool. Inst. Wien **9**:285-294.

REUSS, H. 1903—Die Cercarie und Sporocyste des *Distomum duplicatum* Baer. Zeitschr. wiss. Zool. **74**:458-477.

SEWELL, R. B. 1922—Cercariae indicae. Indian Jour. Med. Research **10** (Supplement):1-370.

SSINITZIN, D. F. 1905—Materialy po estestvennoi istorii trematod. Distomy ryb i liagushek okrestnostei varshavy. 210 p. Varshava.

THIRY, L. 1860—Beiträge zur Kenntniss der *Cercaria macrocerca* Filippi. Zeitschr. wiss. Zool. **10**:271-277.

WAGENER, G. R. 1857—Beiträge zur Entwicklungs-Geschichte der Eingeweidewürmer. Naturk. Verhandel. v. d. Holland. Maatsch. d. Wetensch. te Haarlem, 2 Verzamel., **13**:1-112.

WEST, R. M. 1935—The cercaria of *Neodiplostomum lucidum* La Rue and Bosma. Trans. Amer. Micr. Soc. **54**:15-18.

Scioto River Forms of Chrysococcus

James B. Lackey

The genus Chrysococcus comprises some of the most beautiful of the small flagellates. Despite their small size recognition is easy because they are slow moving, frequently motionless for a long time; because they are practically unharmed by formalin preservation; because their brown color is very pronounced; and because specific characters are based on their resistant shells. They occur in abundance in the Scioto River of Ohio, as well as the Tennessee and Ohio Rivers, but are either scarce elsewhere or have been overlooked or neglected by workers with plankton, for there seems to be no reference to the genus in the writings of American workers. Pascher[1] describes five species, and Fritsch[2] cites the occurence of *C. rufescens* and *C. tesselatus* in England. Only two of the species described by Pascher, *C. rufescens* and *C. punctiformis,* have been noted in the material herewith studied. There is some doubt as to the identification of *C. punctiformis,* for the organisms while abundant in a few preserved samples, were deep brown in color, which with their small size, 2 to 3 microns, rendered identification questionable, especially as their flagella were quite short. *C. rufescens* has at times occurred in large numbers in the Scioto and some of its tributaries as shown by Fig. 1. To

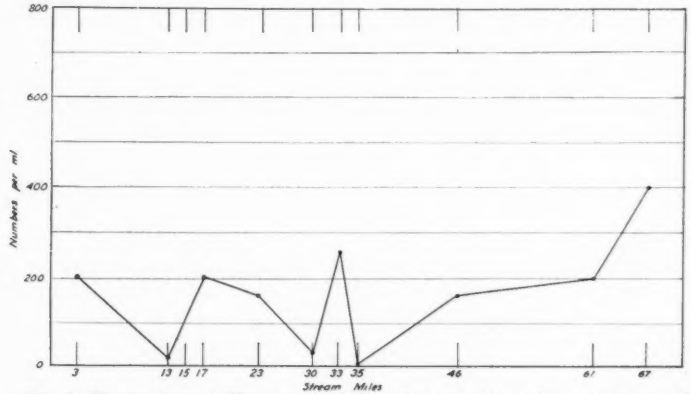


Fig. 1. The numbers of Chrysococcus (all species) per ml. at eleven stations in 67 miles of the Scioto River, Nov. 4, 1937.

1 Pascher, A. and Lemmermann. Die Süsswasserflora Deutschlands, Österreichs und der Schweiz. A. Flagellatae. 2. Gustav Fischer. Jena. 1921.

2 Fritsch, F. E. A Treatise on the British Freshwater Algae. xvii + 1-534 pp. Cambridge Univ. Press, London, 1927.

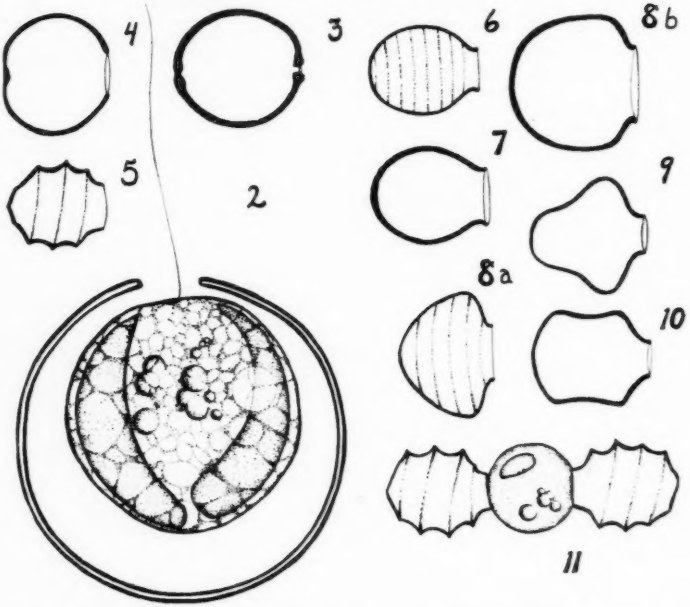
some extent the genus has a seasonal occurrence, being lowest in the winter months, but it has occurred in all months of the year in the Scioto, and is one of the few persistent flagellates in this stream.

The organism presents an interesting study to the taxonomist, relative to the question of variation and species erection. There are seven sharply differentiated morphologic types in the Scioto as far as the shells are concerned, but only two if other structural features be taken into consideration. And yet there is very little intergradation of shell types. Four of them are common in the Scioto; three are rare, but one of these has been noted in some abundance in the Ohio and Tennessee Rivers.

Chrysococcus rufescens is the most abundant. In four random samples 789 individuals of this species were counted to 204 of other species, or 71.27 per cent. It is not always so relatively abundant, however, for in another sample it constituted but 58 per cent while *C. major* comprised 42 per cent, but it is the only species which has occurred consistently. The published description is accurate, but American forms so far examined average smaller. Measurements of 300 specimens indicate an average diameter of $6^{\pm}$ microns. The spherical shape occasionally fails because of a posterior flattening (Fig. 4). Sometimes there is a small tubercle at the back of the shell, inside, and some times the lip of the opening is thickened. Its surface is slightly rough or even covered with small excresences at times, but a magnification of 500 diameters is necessary to see this. The color varies from transparency, presumably in young individuals, to a deep brown which obscures internal structures.

The monad is not visibly attached to the shell, but usually almost fills it. Fig. 3 shows a typical shell of *C. rufescens*, but morphological details can best be seen in C. major, Fig. 2, which differs only in size, and in less intense shell coloration. The most conspicuous feature is a pair of brown chromatophores, parietal in disposition, curved, discoid in shape, and with smooth edges. Occosionally a single one is present. The cyptoplasm is clear and homogeneous and the nucleus is quite small and not visible in the living animal. A large contractile vacuole is median in location. The only inclusions are from one to several spherical bodies which do not respond to tests for glycogen or starch and are presumably oil. There is a single flagellum, about as long as the diameter of the cell. No stigma is present, although *C. hemispherica* frequently shows a small spot reminiscent of the stigma in Dinobryon, but so minute as to leave doubt of its nature.

This description applies to *C. rufescens, C. major, C. ovalis, C. hemisphaerica, C. cylindrica* and *C. amphora. C. spiralis* has but a single chromatophore, which is commonly more green than brown; but a pale green and occasionally pale brown. Its shell (Fig. 5) is a radical departure from that of the other species; is usually 5 to 6 microns long and 4 to 5 wide. It is pale brown in color, smooth and thin. A conspicuous ridge or keel begins at the posterior end and spirals around anteriorly making two and a half turns. The mouth of the shell is practically as large as the barrel. There is prac-



Figs. 2-11. (2) *Chrysococcus major*, optical section showing thickness of shell, two chromatophores, cytoplasmic inclusions, contractile vacuole and flagellum. (3) *C. rufescens*. Shell with posterior tubercle, small opening, thickened margin. (4) *C. rufescens*. Posteriorly flattened shell. (5) *C. spiralis*, shell. (6) *C. ovalis*, shell showing rings. (7) *C. ovalis*, shell. (8a) *C. hemisphaerica*, shell showing rings. (8b) *C. hemisphaerica*, shell. (9) *C. amphora*, shell. (10) *C. cylindrica*, shell. (11) *C. spiralis*. Type of fusion of two individuals occasionally seen.

tically no deviation from this shape, and little variation in size; the organism is unmistakable. *C. spiralis* has been found in the Scioto River; in several of the tributary creeks; in a park lake in Cincinnati and in Clear Water Slough, an ox bow lake in the flood plain of the Little Miami River. It has been found the year round and may be regarded as common. Its greatest recorded numbers were 180 per ml. in Big Walnut Creek on December 9, 1937.

C. major is the largest of the group. It resembles *C. rufescens* but the shell is relatively thinner, never shows the posterior tubercle, or thickened lip, and is rarely deep brown in color. The mouth opening is small. It is never as small as *rufescens*, however, measurements indicate an average of 11± microns, with a variation between 9 and 14 microns. A mixed population of the two species shows a sharply differentiated bimodal curve. *C. major* has never been abundant in the Scioto, but in the Little Miami valley has occurred in large numbers.

Since its size approximates that of *Trachelomonas volvocina* it might readily be mistaken for that organism in counting live plankton samples. But its flagellum is not long; there is no conspicuous stigma, and at 125 diameters its movement is an even, slow one while that of *T. volvocina* is a rapid jerky motion.

C. ovalis (Figs. 6 and 7) is probably next to *C. rufescens* in abundance. It averages 5± microns in length and is almost as wide. The shape rarely varies, although the rim of the mouth sometimes flares a bit, and the shell may show four or five encircling small depressions giving a ringed appearance. The mouth opening is large. The shell color at times is decidedly melanic. No posterior tubercle has ever been noted.

C. hemisphaerica (Fig. 8) is nearest to *ovalis,* but easily differentiated by its truncate anterior end. It has a large mouth, and is usually annulate, but its longest axis is usually the transverse one. Its chief variation is the flare of the lip and the distinctness of the rings. This seems due to the degree to which they are depressed. This species is next to *major* in size, averaging 8 in width and 7 in length. It is common.

The two remaining species are quite rare in the Scioto, although *cylindrica* has been noted in some abundance in the Tennessee. *Amphora* is shown in Fig. 9, and presents some similarity to *hemisphaerica.* The mouth is comparatively smaller, has never been observed to flare, and annulate shells have never been seen. It is a large form, approximately 10 x 8.5 microns, and usually bright brown in color, with a thin shell.

C. cylindrica (Fig. 10) is likewise a thin shelled form, about 6 microns long. It is smooth in contour and has a small mouth, relatively larger, however, than *rufescens.* The median diminution of the shell is its most characteristic and unmistakable feature. In color it agrees with *rufescens,* but the shell is generally thinner and never shows a posterior tubercle.

The above forms of Chrysococcus are sufficiently sharply defined to be picked out at once, and in a mixed sample, the various types are easily counted. To give species rank to the seven types described, however, raises the vexed question of how far should we go with species creation. In this case shell characters are the species limits, and are well defined with but little intergradation, for all bu *C. major.* It is not possible to pick out a long series of intergrading forms, as between *Trachelomonas Crebea* Kellicott and *T. fluviatilis* Lemm. The validity of *C. major* as a separate species might be questionable, but its status is indicated by the bimodal curve referred to above. The validity of the other proposed species is not considered doubtful, especially in a group where shell characters are so important.

These organisms have occasionally shown a behaviour which is puzzling and might indicate sexual processes in a group where sex is at present unknown. Fig. 11 shows two shells of *C. spiralis* attached by the mouth end to a clear globule of extruded protoplasm. Within this is a single chromatophore and a few small oil globules. Such possible conjugation has been most

commonly noted in *C. spiralis*, but has also been noted in *C. hemisphaerica*. In view of the lack of knowledge of reproduction in this genus, this behaviour at present cannot be interpreted. It is hardly a plastogamic occurrence because of the apparent fusion of the contents of the two cells, but its real significance must remain in doubt for the present.

This group also raises the question as to whether a true river plankton exists. A very large number of pools and ponds have been examined over a period of years and only two of the species *C. rufescens* and *C. spiralis* have been found elsewhere than in rivers, river tributaries or bodies of water adjacent to, and subject to periodic overflow by rivers. In a single hilltop pond in a small Cincinnati park, the two excepted species have been found, and at one time this pond was supplied with Ohio River water coming through the city water supply. Certainly this group is more typical of rivers, or at least of the Ohio and Tennessee river systems, than of other locations, although they may easily have been overlooked by observers generally, on account of their small size.

U. S. Public Health Service,
Stream Pollution Investigations,
Cincinnati, Ohio.

Preliminary Report of the Phytoplankton of the Gulf of Maine[1]

Lois C. Lillick

A detailed survey of the biology of the offshore waters of the Gulf of Maine was made under the direction of Dr. A. C. Redfield by the Woods Hole Oceanographic Institution in 1933 and 1934, during which time the institution's research ketch "Atlantis" made frequent cruises into the gulf. There was no botanist associated with the laboratory at that time, but phytoplankton collections were made and stored in the hope that some one would be found to carry on this phase of the survey. In the summer of 1936 the writer undertook to work up the material, and the present paper is the resulting account of the phytoplankton.

The investigation was undertaken while the writer was a research fellow at the Woods Hole Oceanographic Institution and a student at the University of Michigan. During the past year an exchange fellowship from the University of Michigan to Radcliffe College has made possible the completion of the work. Much assistance and guidance during the course of the investigation has been received from Professor Wm. Randolph Taylor of the University of Michigan and the Marine Biological Laboratory, Woods Hole, and Professors H. B. Bigelow and A. C. Redfield of Harvard University and the Woods Hole Oceanographic Institution, for all of which the writer is deeply indebted. This paper comprises but a preliminary report. A more detailed account is in the process of preparation.

Collections were begun in September, 1933 and were made nearly every month thereafter until July, 1934. Water bottle samples were taken at 1, 10, 30, 50, and 80 meters depth. In addition net hauls were made in April and May, 1934, and August, 1936. Cruises were spaced farther apart than is desirable, but in spite of this, there is good evidence that none of the major phases of the phytoplankton cycle were missed. Both qualitative and quantitative analyses of the material were made, the results of which are best expressed in tabular form.

In Tables 1 to 3 are given lists of all species found during the survey, together with their seasonal occurrence. A great number of species in widely separated groups were represented in the phytoplankton collections. The importance of the diatoms overshadowed that of all other classes as it normally does in these latitudes. Of this group 25 genera and 69 species and varieties were identified, though the total number now known for the gulf exceeds this considerably. The Dinophyceae, of which 11 genera and 44 species were found, were of secondary importance. As yet the taxonomic work on this group has not been completed, therefore this number will probably be

1 Papers from the Department of Botany of the University of Michigan No. 673; Contribution No. 189 of the Woods Hole Oceanographic Institution.

increased. Of lesser consequence are the Chrysophyceae, represented by the Silicoflagellata and Coccolithophoridaceae, the Myxophyceae, and certain unclassified flagellates. In making taxonomic determinations the following authorities were used: Bacillariophyceae, Gran (1908), Hustedt (1930 et seq.); Dinophyceae, Paulsen (1908), Lebour (1925), Schiller (1931); Coccolithophoridaceae, Schiller (1930); and Silicoflagellata, Gemeinhardt (1930). The terminology used by Fritch (1935) has been followed.

For the quantitative determinations the precipitation method developed by Nielsen and von Brand (1934) was followed. April, May and August results are based upon corrected vertical net tows rather than water bottle samples, in which cases the quantity of plankton is expressed as the number of cells found under one tenth of a square meter of surface, an area selected because it approximates that of the net used. It is not practical to publish here all the tables obtained, therefore those given (Tables 4 to 37) are ones selected from representative parts of the gulf at the different seasons. The approxi-

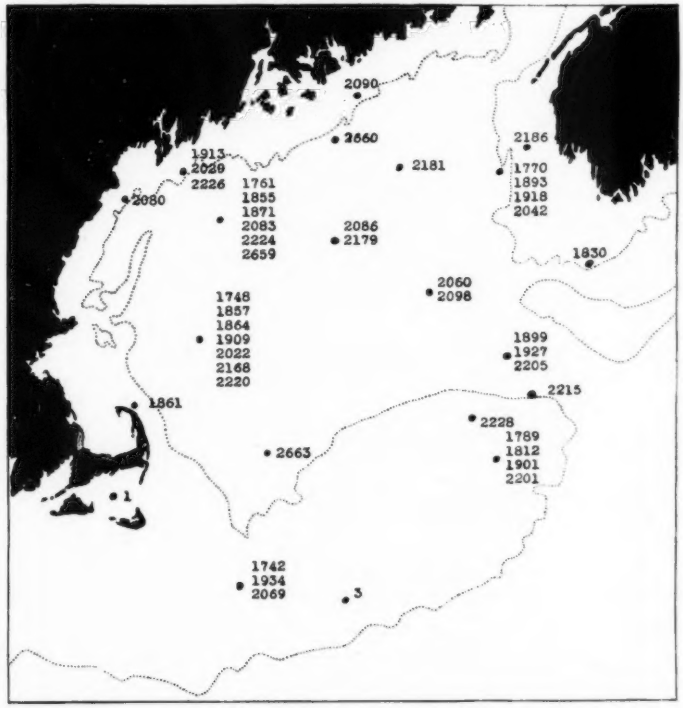


Fig. 1. Approximate locations of "Atlantis" stations in the Gulf of Maine, 1933-1934.

mate locations of the stations for which tables are given are shown in Fig. 1.

From both the quantitative and qualitative charts it can be seen that the phytoplankton of the Gulf of Maine follows the cycle that is typical of boreal seas. There is an intense flowering of diatoms in the spring, followed by a summer lull. Late in summer a minor diatom flowering arises, quickly succeeded by the scant winter population. All discussion of the significance of these data is being reserved for the more detailed account.

REFERENCES

FRITCH, F. E. 1935—The structure and reproduction of the Algae. I. xvii + 791. Cambridge, England.

GEMEINHARDT, K. 1930—Silicoflagellatae. Rabenhorst's Kryptogamenflora Deutschlands, Österreichs, und der Schweiz **10**(2):1-87. Leipzig.

GRAN, H. H. 1908—Diatomeen. K. Brandt u. C. Apstein, Nordisches Plankton **19**:1-146. Kiel u. Leipzig.

HUSTEDT, F. 1930—Die Kieselalgen. Rabenhorst's Kryptogamen-flora Deutschlands, Österreichs, und der Schweiz **7**(1). Leipzig.

LEBOUR, M. V. 1925—The dinoflagellates of northern seas. Plymouth.

NIELSEN, E. S. AND TH. V. BRAND. 1934—Quantitative Zentrifugenmethoden, zur Planktonbestimmung. Cons. Perm. int. pour Explor. de la Mer. Rapp. et Proc. Verb. **59**:99-100.

PAULSEN, O. 1907—Peridiniales. K. Brandt u. C. Apstein, Nordisches Plankton **18**:1-116. Kiel u. Leipzig.

SCHILLER, J. 1930—Coccolithineae. Rabenhorst's Kryptogamen-flora Deutschlands, Österreichs, und der Schweiz **10**(2):89-273. Leipzig.

———1931—Dinoflagellates. Ibid. **10**(3). Leipzig.

TABLE 1

Bacillariophyceae	No. of Stations at which present								
	Sept.	Oct.	Dec.	Jan.	March	April	May	June	August
No. of stations made	11	7	8	10	11	73	48	6	11
Achnanthes taeniata Grun.	–	–	–	–	–	17	1	–	–
Actinoptychus undulatus (Bail.) Ralfs	1	1	1	1	1	–	2	1	1
Biddulphia aurita (Lyngbye) Breb. et Godey	–	–	–	–	–	9	3	–	–
Cerataulina Bergoni Per.	–	–	–	1	–	–	–	–	–
Chaetoceros spp.	1	1	–	–	1	7	–	–	–
Ch. affinis Laud.	–	–	–	–	–	37	4	–	3
Ch. atlanticus Cleve	–	–	–	–	–	19	6	–	2
Ch. borealis Bail.	–	–	–	–	1	1	1	–	1
Ch. borealis var. *concavicornis*	–	–	–	–	–	5	10	–	–
Ch. compressus Laud.	–	–	–	–	–	2	1	–	1
Ch. constrictus Gran	–	–	–	–	–	28	9	–	–
Ch. convolutus Castr.	–	–	–	–	–	44	10	–	–
Ch. debilis Cleve	–	–	–	–	1	29	9	–	–
Ch. decipiens Cleve	–	–	–	1	1	19	15	3	4
Ch. diadema (Ehr.) Gran	–	–	–	–	–	33	2	–	–
Ch. didymus Ehr.	–	–	–	–	–	19	10	–	1
Ch. furcellatus Bail.	–	–	–	–	–	9	9	1	–

TABLE 1 (Continued)

	Sept.	Oct.	Dec.	Jan.	March	April	May	June	August
Ch. laciniosus Schütt	–	–	–	–	–	26	6	–	1
Ch. lorenzianus Grun.	–	–	–	–	–	1	–	–	–
Ch. pseudocrinitus Ostf.	–	–	–	–	–	–	–	–	1
Ch. radians Schütt	–	–	–	–	–	29	–	–	–
Ch. socialis Laud.	–	–	–	–	–	1	–	–	–
Ch. subsecundus (Grun.) Hust.	–	–	–	–	–	1	–	–	–
Ch. teres Cleve	–	–	–	–	–	6	–	–	1
Cocconeis Scutellum Ehr.	–	–	–	–	1	–	–	–	–
Corethron hystrix Hensen	–	–	1	1	–	3	–	–	1
Coscinodiscus spp.	2	–	1	–	–	–	1	–	1
C. centralis Ehr.	2	3	5	9	3	12	24	–	4
C. excentricus Ehr.	3	4	7	8	1	5	1	1	3
C. radiatus Ehr.	–	–	–	–	–	–	4	–	–
Cyclotella sp.	–	–	–	1	–	–	–	–	–
Detonula confervacea (Cleve) Gran	–	–	–	1	1	11	2	–	–
Eucampia zoodiacus Ehr.	–	–	–	–	–	6	–	–	–
Fragillaria sp.	–	–	–	–	–	1	–	–	–
Grammatophora marina (Lyngb.) Kütz.	1	–	1	–	–	–	–	–	–
Guinardia flaccida Prerag.	7	–	–	1	–	–	–	1	9
Leptocylindrus danicus Cleve	–	–	–	2	–	3	3	–	3
Lichmophora abbreviata Ag.	–	–	–	–	–	–	–	–	1
Melosira sp.	–	–	–	1	–	3	–	–	–
M. sulcata (Ehr.) Kütz.	3	3	3	3	4	1	7	2	1
Navicula sp.	2	2	1	–	–	–	–	–	–
N. distans W. Smith	–	1	–	2	1	3	7	1	4
N. Vanhoeffenii Cleve	–	–	–	–	2	–	–	–	–
Nitzschia Closterium W. Smith	–	–	–	2	1	11	2	–	6
N. delicatissima Cleve	–	–	–	–	–	–	–	1	–
N. longissima Cleve	–	–	–	6	–	–	–	2	–
N. seriata Cleve	–	–	–	1	2	–	–	–	–
Pinnularia sp.	1	–	–	–	–	–	–	1	–
Pleurosigma Normani Ralfs	1	–	1	4	4	4	4	1	4
Porosira glacialis (Grun.) Jörg.	–	–	–	–	4	46	12	–	–
Rhizosolenia spp.	–	1	–	–	2	–	–	3	–
Rh. alata Brightw.	1	–	–	–	6	5	–	–	7
Rh. Bergoni Perag.	–	–	–	–	–	2	–	–	–
Rh. calcar-avis Cleve	–	–	–	–	–	–	–	–	1
Rh. fragilissima Bergon.	–	–	–	–	–	2	–	–	–
Rh. hebatata var. *semispina* (Hensen) Gran	1	–	–	–	–	6	4	–	4
Rh. imbricata var. *Shrubsolei* (Cleve) Schroeder	–	–	–	–	1	38	8	–	3
Rh. setigera Brightw.	1	–	–	–	–	–	–	–	–
Rh. styliformis Brightw.	–	–	–	–	–	–	–	–	5
Sceletonema costatum (Grev.) Cleve	–	–	–	4	1	–	–	1	2
Thalassionema nitzschioides Grun.	7	–	3	8	4	21	3	2	–
Thalassiosira spp.	1	–	2	5	1	–	–	1	–
Th. bioculata (Grun.) Ostf.	1	–	–	–	2	–	–	–	–
Th. decipiens (Grun.) Jörg.	–	1	2	8	4	–	–	3	–
Th. gravida Cleve	–	–	–	–	1	2	–	–	–
Th. hyalina (Grun.) Gran	1	–	–	–	1	26	2	–	–
Th. Nordenskioeldii Cleve	6	2	1	3	9	59	16	4	2
Thalassiothrix longissima Cleve and Grun.	–	–	–	–	–	1	–	–	–
Triceratium alternans Bail.	–	–	–	1	–	–	–	–	–

TABLE 2

Dinophyceae	No. of Stations at which present								
	Sept.	Oct.	Dec.	Jan.	March	April	May	June	August
Amphidinium oceanicum Lohm.	1	–	–	–	–	–	–	–	–
Ceratium bucephalum (Cleve) Cleve	–	–	–	–	–	–	–	–	1
C. Fusus (Ehr.) Duj.	4	2	2	3	1	2	4	1	8
C. lineatum (Ehr.) Gran	4	3	2	4	–	–	–	–	2
C. longipes (Bail.) Gran	4	1	–	1	1	–	17	1	6
C. macroceros (Ehr.) Cleve	–	–	–	–	–	–	–	–	3
C. tripos (O.F.M.) Nitzsch.	2	3	2	4	2	3	2	–	8
C. tripos var. *atlanticum* Ostf.	–	–	–	–	–	–	–	–	9
C. tripos f. *subsalsum* Ostf.	–	–	–	–	–	–	–	–	4
Dinophysis spp.	–	–	1	–	–	–	–	–	2
D. acuminata Clap & Lach.	4	1	–	–	–	3	–	1	2
D. norvegica Clap & Lach.	–	–	–	–	–	–	–	–	1
D. Ovum Schütt	1	1	1	–	–	1	–	1	2
D. robusta Gran & Bra.	1	–	–	–	–	–	–	–	–
D. sphaerica Stein	–	1	–	–	–	–	–	–	–
Exuviaella spp.	2	6	4	1	–	–	–	–	–
E. baltica Lohm.	–	1	–	2	1	–	–	–	–
E. marina Cienkowski	5	1	–	6	1	–	–	1	–
Goniaulax spp.	–	2	1	–	–	4	1	–	–
G. tamarensis Lebour	1	1	1	–	–	–	1	–	2
Mesoporos perforata (Gran) Lillick	–	–	5	–	–	–	–	–	–
Noctiluca miliaris Sur.	–	–	1	–	–	–	6	–	4
Peridinium spp.	8	5	1	4	1	14	40	3	9
P. americanum Gran & Bra.	1	2	–	–	–	–	–	–	–
P. breve Paulsen	1	4	–	–	1	–	–	–	–
P. conicoides Paulsen	–	2	1	–	–	–	–	–	–
P. conicum (Gran) Ostf. & Schmidt	–	–	–	–	–	17	–	1	–
P. conicum var. *Asamushi*	1	1	1	–	–	–	–	–	–
P. crassipes Paulsen	–	–	–	–	–	–	–	–	4
P. denticulatum Gran & Bra.	1	2	–	–	1	–	–	–	–
P. depressum Bail.	1	–	1	–	1	9	12	1	3
P. Granii Ostf.	–	1	–	1	2	–	–	–	–
P. minusculum Pav.	–	1	–	1	–	–	–	–	–
P. novascotiense Gran & Bra.	–	1	–	–	–	–	–	1	–
P. simplex Gran & Bra.	2	3	–	2	2	–	–	1	–
P. trochoideum Smith	5	–	–	–	–	–	1	–	–
Phalocroma sp.	–	–	–	1	1	–	–	–	–
P. parvulum (Schütt) Jörg.	–	–	–	1	–	–	–	–	–
Prorocentrum micans Ehr.	4	3	3	3	–	–	–	–	1
P. minimum Schiller	–	–	1	–	–	–	–	–	–
P. Scutellum Schröder	–	–	–	–	–	1	1	1	1

TABLE 3

Coccolithophoridaceae, Silicoflagellata, etc.	No. of Stations at which present								
	Sept.	Oct.	Dec.	Jan.	March	April	May	June	August
Acanthoica acanthifera Lohm.	1	–	–	–	–	–	–	1	–
A. acanthos Schiller	9	3	4	8	6	–	–	1	–
A. coronata Lohm.	–	–	–	–	1	–	–	–	–
A. monospina Schiller	1	–	–	–	1	–	–	–	–
Calytrosphaera uvella Schiller	–	–	–	–	1	–	–	–	–
Coccolithus pelagicus (Wall.) Schiller	–	–	–	1	–	–	–	–	–
Discosphaera tubifer (Murr. & Blackman) Lohm.	–	–	–	–	1	–	–	–	–
Lohmanosphaera sp.	–	–	–	1	1	–	–	–	–
L. adriatica Schiller	–	–	–	–	1	–	–	–	–
Pontosphaera Bigelowi Gran & Bra.	1	–	–	–	–	–	–	–	–
P. Huxleyi Lohm.	5	2	–	3	1	–	–	1	2
P. ovalis Schiller	–	–	–	1	–	–	–	–	–
Rhabdosphaera stylifer Lohm.	–	1	–	1	1	–	–	–	–
R. tubulosa Schiller	–	–	–	1	–	–	–	–	–
Scyphosphaera Apsteini Lohm.	–	–	–	–	1	–	–	–	–
Syracosphaera sp.	6	–	–	–	1	–	–	–	–
S. mediterranea Lohm.	–	–	–	–	1	–	–	–	–
S. pulchra Lohm.	–	1	–	–	–	–	–	–	–
Dictyocha fibula Ehr.	1	1	–	1	1	–	–	1	–
D. fibula var. *messanensis* (Haek.) Lemm.	–	–	–	–	–	–	–	2	–
Distephanus speculum (Ehr.) Haek.	1	–	–	2	–	3	–	–	2
Ebria antiqua Schulz	–	–	1	–	–	–	–	–	–
E. tripartita (Schum.) Lemm.	–	–	–	–	–	1	–	–	–
Gloeocapsa sp.	1	–	–	1	–	–	–	–	–
Merismopedia sp.	–	–	–	1	–	–	–	–	–
Flagellates, Spores, etc.	9	6	5	9	4	1	–	5	–

TABLE 4.—September, 1933. Station 1742.

Species	Depth	Cells per Liter				
		1 m.	10 m.	30 m.	50 m.	75 m.
Actinoptychus undulatus		--	--	55	--	--
Coscinodiscus centralis		--	--	55	--	--
Guinardia flaccida		--	--	55	--	--
Navicula distans?		--	55	--	--	55
Nitschia Closterium		--	--	--	55	--
Thalassionema nitzschioides		--	--	220	55	--
Thalassiosira Nordenskioeldii		--	220	165	330	--
Ceratium lineatum		--	--	275	55	--
C. longipes		--	--	55	--	--
Dinophysis acuminata		--	--	55	--	--
Peridinium trochoideum		--	--	275	--	--
P. simplex		--	--	165	--	--
Prorocentrum micans		--	--	55	--	--
Acanthoica acanthos		--	110	--	--	--
Pontosphaera Huxleyi		--	--	55	--	--
Flagellates		220	220	440	385	--
Protozoa		165	110	--	--	110

TABLE 5.—September, 1933. Station 1748.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Thalassiosira sp.		110	--	--	--	--
Ceratium tripos		55	--	--	--	--
Peridinium trochoideum		500	385	--	110	110
Acanthoica acanthos		--	55	--	--	110
Spores, flagellates		1000	100	330	330	110
Protozoa		--	--	55	--	--

TABLE 6.—September, 1933. Station 1761

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Navicula sp.		--	--	220	--	--
Thalassionema nitzschioides		--	--	220	--	--
Thalassiosira sp.		55	--	--	--	--
Peridinium sp.		--	110	--	--	--
P. americanum		220	--	--	--	--
Syracosphaera		165	110	550	--	--
Gloeocapsa (Colony)		110	--	--	--	--
Flagellates		165	220	220	--	--
Protozoa		110	--	--	--	--

TABLE 7.—September, 1933. Station 1770.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus sp.		--	--	--	--	55
Guinardia flaccida		--	--	--	110	55
Nitzschia Closterium		--	--	55	--	--
Pinnularia sp.		--	55	--	--	--
Ceratium Fusus		--	110	--	--	--
Exuviaella marina		770	165	--	--	--
Peridinium sp.		4500	330	--	--	--
P. breve		--	--	--	--	55
Acanthoica acanthos		330	--	220	--	--
Pontoshpaera Huxleyi		--	--	55	--	--
Syrachosphaera		330	--	--	--	--
Phaeocystis sp.		--	--	220	--	--
Flagellates		440	440	820	--	550
Protozoa		660	55	--	55	55

TABLE 8.—September, 1933. Station 1789

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	45 m.
Coscinodiscus centralis		--	--	180	--
C. excentricus		65	--	--	--
Guinardia flaccida		200	--	23,300	12,000
Melosira sulcata		20	--	155	--
Navicula distans?		45	45	110	65
Pleurosigma Normani		65	110	90	45
Rhizosolenia setigera		--	--	110	--
Thalassionem nitzschioides		810	330	3,150	2,440
Thalassiosira bioculata		65	--	45	--
Th. Nordenskioeldii		--	285	1,000	90
Ceratium Fusus		45	--	20	20
C. lineatum		155	--	460	220
C. longipes		45	--	--	--
C. tripos		--	--	--	20
Dinophysis acuminata		20	20	--	65
D. Ovum		45	--	--	--
Goniaulax tamarensis		--	--	110	--
Peridinium sp.		155	--	--	90
P. depressum		--	175	90	65
Prorocentrum micans		110	90	310	350
Acanthoica acanthos		--	20	--	--
Pontosphaera Huxleyi		--	--	65	--
Dictyocha fibula		20	--	--	--
Flagellates		--	--	375	175
Protozoa		90	--	20	--

TABLE 9.—October, 1933. Station 1812.

Species	Depth	Cells per Liter 10 m.	30 m.	55 m.
Coscinodiscus centralis		20	65	--
C. excentricus		1585	660	495
Melosira sulcata		65	110	--
Navicula distans		20	20	20
Rhizosolenia sp.		--	--	45
Thalassiosira sp.		200	--	65
Ceratium Fusus		65	90	110
C. lineatum		200	20	45
C. tripos		--	--	20
Dinophysis acuminata		20	--	--
D. Ovum		45	65	110
Exuviaella marina		90	90	220
Goniaulax sp.		45	--	--
Peridinium sp.		20	--	--
P. breve		175	--	--
P. denticulatum		65	--	--
P. conicoides		--	--	65
P. conicum		--	90	--
P. simplex		--	20	--
Procentrum micans		2500	950	1600
Acanthoica acanthos		65	--	65
Flagellates		525	90	330
Protozoa		20	90	45

TABLE 10.—October, 1933. Station 1830

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Actinoptychus undulatus		--	--	--	--	110
Melosira sulcata		--	--	175	640	1550
Navicula distans		--	--	45	20	130
N. Vanhoeffeni		--	--	--	--	155
Thalassiosira Nordenskioeldii		20	--	45	45	--
Ceratium tripos		--	--	20	--	--
Goniaulax sp.		--	--	--	20	--
Peridinium sp.		--	--	--	20	--
Pontosphaera Huxleyi		--	--	200	65	200
Rhabdosphaera styliformis		--	--	--	20	--
Syrachosphaera pulchra		--	--	--	90	--
Dictyocha fibula		--	--	--	20	--
Flagellates		--	--	175	65	45
Protozoa		--	--	45	200	375

TABLE 11.—October, 1933. Station 1855.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		--	20	--	--	20
Melosira sulcata		--	20	--	--	--
Exuviaella sp.		220	--	--	--	--
Peridinium sp.		--	--	--	20	--
Flagellates		20	640	--	110	--
Protozoa		45	130	--	--	--

TABLE 12.—October, 1933. Station 1857.

Species	Depth	Cells per Liter 1 m.	10 m.	50 m.	80 m.
Coscinodiscus excentricus		20	20	--	45
Exuviaella sp.		45	20	155	110
Peridinium conicoides		--	--	20	--
Flagellates		200	45	2290	90
Protozoa		20	20	--	--

TABLE 13.—October, 1933. Station 1860.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		45	--	--	45	--
C. excentricus		20	--	45	--	80
Ceratium Fusus		--	20	--	--	--
C. longipes		--	--	20	--	--
C. tripos		--	--	20	--	--
Exuviaella sp.		45	90	--	--	--
Peridinium sp.		--	--	--	20	--
Flagellates		--	--	--	20	--
Protozoa		--	90	--	90	20

TABLE 14.—December, 1933. Station 1864.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		110	45	--	--	--
C. excentricus		--	20	--	45	20
Exuviaella sp.		--	--	20	--	--
E. minima		55	--	--	--	--
Ebria antiqua		55	--	--	--	--
Flagellates		--	45	20	--	20
Protozoa		--	20	--	20	--

TABLE 15.—December, 1933. Station 1871.

Species	Depth	Cells per Liter 1 m.	30 m.	50 m.	80 m.
Actinoptychus undulatus		110	--	--	--
Coscinodiscus centralis		--	65	--	20
C. excentricus		--	110	--	45
Melosira sulcata		--	--	--	155
Navicula distans?		--	20	--	--
Thalassiosira decipiens		--	65	--	20
Exuviaella sp.		--	20	--	20
Acanthoica acanthos		--	--	--	20
Flagellates		--	155	--	--
Protozoa		--	65	--	--

TABLE 16.—December, 1933. Station 1893.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	80 m.
Coscinodiscus excentricus		--	200	--	--
Thalassionema nitzschioides		--	--	--	440
Thalassiosira sp.		--	--	--	220
Ceratium tripos		--	--	20	--
Exuviaella sp.		--	285	20	--
Acanthoica acanthos		20	20	--	220
Flagellates		--	65	--	110
Protozoa		65	155	110	--

TABLE 17.—December, 1933. Station 1899.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		--	--	--	20	--
C. excentricus		--	--	45	--	--
Thalassionema nitzschioides		220	--	--	--	--
Thalassiosira sp.		110	--	--	--	--
Exuviaella sp.		--	--	--	45	--
Acanthoica acanthos		110	--	--	65	20
Coccolithus sp.		--	--	--	--	65
Flagellates		330	--	155	65	110
Protozoa		110	--	110	155	--

TABLE 18.—December, 1933. Station 1901.

Species	Depth	Cells per Liter 1 m.	10 m.
Corethon hystrix		45	20
Coscinodiscus sp.		45	--
C. centralis		20	110
C. excentricus		200	65
Grammatophora marina		20	--
Melosira sulcata		90	90
Thalassionema nitzschioides		265	65
Ceratium Fusus		20	--
C. lineatum		45	20
C. tripos		45	20
Dinophysis acuminata		--	20
D. Ovum		20	--
Exuviaella sp.		20	110
Gymnidinium sp.		--	65
Noctiluca miliaris		45	--
Peridinium sp.		45	90
P. conicoides		--	65
Prorocentrum micans		375	375
Acanthoica acanthos		20	--
Flagellates		240	200
Protozoa		240	330

TABLE 19.—January, 1934. Station 1909.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		--	--	65	65	45
C. excentricus		65	175	265	240	110
Melosira sulcata		20	--	20	20	20
Nitzschia longissima		--	45	--	--	--
Thalassiosira decipiens		20	--	--	20	--
Ceratium tripos		--	--	--	20	--
Acanthoica acanthos		20	--	--	--	--
Pontosphaera Huxleyi		20	65	20	90	--
Rhabdosphaera tubulosa		--	--	40	--	--
Flagellates		65	65	110	220	--
Protozoa		20	--	--	--	--

TABLE 20.—January, 1934. Station 1913.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		--	--	--	65	90
C. excentricus		175	45	65	90	155
Melosira sulcate		330	155	--	175	220
Navicula sp.		--	45	90	20	20
Nitzschioides longissima		110	20	--	--	--
Pleurosigma Normani		--	--	65	45	45
Thalassionema nitzschioides		130	45	--	--	--
Thalassiosira decipiens		130	20	155	375	155
Ceratium Fusus		--	--	--	20	--
Exuviaella baltica		90	--	--	20	--
Flagellates		110	20	20	20	20
Protozoa		45	--	--	--	20

TABLE 21.—January, 1934. Station 1918.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Coscinodiscus centralis		--	--	20	--	20
Leptocylindrus danicus		--	--	90	--	--
Nitzschia longissima		--	--	20	--	--
Sceletonema costatum		--	--	--	--	45
Thalassiosira decipiens		--	--	90	--	--
Ceratium Fusus		--	20	--	--	--
Exuviaella marina		--	20	--	--	--
Acanthoica acanthos		20	--	20	--	45
Flagellates		--	--	330	20	65
Protozoa		45	20	45	45	--

TABLE 22.—January, 1934. Station 1927.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.
Coscinodiscus centralis		--	20	45	--
Leptocylindrus danicus		--	--	90	--
Nitzschia longissima		--	--	45	20
Thalassionema nitzschioides		130	--	--	--
Thalassiosira decipiens		--	20	45	--
Th. Nordenskioeldii		--	--	--	90
Ceratium Fusus		--	--	20	--
C. lineatum		--	20	--	--
Exuviaella marina		45	--	--	--
Peridinium sp.		--	--	--	65
Flagellates		110	110	90	20
Protozoa		45	--	45	20

TABLE 23.—January, 1934. Station 1934.

Species	Depth	Cells per Liter 1 m.	30 m.	50 m.
Actinoptychus undulatus		--	--	110
Coscinodiscus centralis		400	400	350
C. excentricus		200	350	220
Cyclotella sp.		20	--	--
Leptocylindrus danicus		155	--	--
Melosira sulcata		--	285	--
Nitzschia longissima		20	--	--
Pleurosigma Normani		20	45	--
Thalassionema nitzschioides		1475	1780	2795
Thalassiosira Nordenskioeldii		920	285	240
Triaceratium alternans		45	--	--
Ceratium lineatum		65	--	20
C. tripos		--	20	45
Exuviaella marina		--	--	65
Prorocentrum micans		110	330	265
Acanthoica acanthos		20	--	--
Dictyocha fibula		20	--	--
Flagellates		155	20	--
Protozoa		45	45	45

TABLE 24.—March, 1934. Station 2022

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.	80 m.
Detonula confervacea		110	--	--	--	--
Rhizosolenia alata		275	385	--	--	--
Ceratium tripos		--	55	--	--	--

TABLE 25.—March, 1934. Station 2029.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	45 m.
Chaetoceros sp.		--	--	880	--
Pleurosigma Normani		440	110	330	--
Porosira glacialis		6050	5107	7050	6600
Rhizosolenia alata		--	--	110	--
Thalassiosira hyalina		--	--	1210	--
Th. Nordenskioeldii		9250	6500	16250	33200
Peridinium sp.		110	--	--	--
P. americanum		220	--	--	--
Protozoa		--	550	220	220

TABLE 26.—March, 1934. Station 2042.

Species	Depth	Cells per Liter 10 m.	30 m.	50 m.	80 m.
Cocconeis Scutellum		--	--	110	--
Rhizosolenia alata		--	--	1210	--
Rh. Shrubsolei		--	--	220	--
Thalassionema nitzschioides		--	--	1320	--
Thalassiosira Nordenskioeldii		--	330	220	--
Ceratium Fusus		--	--	330	--
Exuviaella baltica		--	--	1100	660
Peridinium sp.		330	--	--	--
Syracosphaera sp.		--	--	110	165
Flagellates		--	--	1550	275
Protozoa		--	--	220	55

TABLE 27.—March, 1934. Station 2060.

Species	Depth	Cells per Liter 1-10 m.	30 m.	50 m.	80 m.
Nitzschia longissima		20	--	--	--
Thalassiosira Nordenskioeldii		45	--	90	--
Acanthoica acanthos		--	--	--	45
Syracosphaera sp.		65	--	--	--
Flagellates		65	--	--	--
Protozoa		130	--	--	--

Table 28.—March, 1934. Station 2069.

Species	Depth	Cells per Liter 7 m.	27 m.
Actinoptychus undulatus		330	240
Coscinodiscus centralis		550	550
C. excentricus		1130	175
Navicula Vanhoeffeni		5000	3400
Nitzschia Closterium		--	45
Pleurosigma Normani		110	--
Porosira glacialis		460	410
Thalassionema nitzschioides		4160	990
Thalassiosira decipiens		--	850
Th. Nordenskioeldii		--	265
Ceratium longipes		--	20
Peridinium breve		--	90
P. denticulatum		20	--
P. depressum		20	--
Phalocroma sp.		65	--
Flagellates		20	--
Protozoa		110	65

Table 29.—April, 1934. Cells per column of water 1/10 M.²

Species	Station 2080	2083	2086
Achnanthes taeniata	----	----	14,200,000
Chaetoceros diadema	286,350,000	----	58,500,000
Ch. atlanticus	----	----	3,366,000
Ch. constrictus	4,945,000	----	3,978,000
Ch. convolutus	115,000	1,260,000	104,000,000
Ch. debilis	9,200,000	----	4,750,000
Ch. decipiens	690,000	----	2,210,000
Ch. compressus	11,530,000	----	30,500,000
Ch. didymus	21,610,000	----	5,700,000
Ch. laciniosus	3,565,000	----	612,000
Ch. lorenzianus	3,450,000	----	----
Ch. radians	41,000,000	----	15,000,000
Ch. teres	560,000	----	----
Melosira sp.	----	----	790,000
Navicula distans	230,000	----	----
Porosira glacialis	----	----	65,600,000
Rhizosolenia semispina	----	----	29,000,000
Thalassiosira Nordenskioeldii	63,500,000	----	20,700,000

Table 30.—April, 1934. Cells per Column.

Species	Station 2090	2098	2115
Achnanthes taeniata	32,300,000	572,500,000	3,220,000
Biddulphia aurita	655,000	----	----
Chaetoceros spp.	----	----	2,780,000
Ch. atlanticus	2,400,000	545,000,000	26,900,000
Ch. constrictus	437,000	----	----
Ch. convolutus	32,500,000	----	----
Ch. debilis	3,060,000	17,920,000	880,000
Ch. decipiens	11,800,000	----	----
Ch. diadema	2,400,000	620,000,000	33,500,000
Ch. didymus	13,550,000	----	----
Ch. laciniosus	5,900,000	----	4,980,000

Ch. radians	13,550,000	29,000,000	12,450,000
Corethran hystrix	----	1,380,000	----
Coscinodiscus centralis	----	----	146,000
Detonula confervacea	----	----	439,000
Leptocylindrus danicus	1,310,000	----	----
Navicula sp.	1,920,000	1,380,000	293,000
Nitzschia Closterium	218,200	----	732,000
Porosira glacialis	670,000,000	3,190,000,000	15,400,000
Rhizosolenia Shrubsolei	2,620,000	19,310,000	732,000
Thalassionema nitzschioides	4,370,000	----	2,050,000
Thalassiosira hyalina	31,500,000	567,000,000	11,300,000
Th. Nordenskioeldii	657,500,000	7,600,000,000	109,500,000
Thalassiothrix longissima	----	6,900,000	----
Peridinium spp.	----	1,380,000	293,000
P. conicum	437,000	----	----

TABLE 31.—May, 1934. Cells per Column.

Species Station	2168	2179	2121
Biddulphia aurita	234,000	----	----
Chaetoceros atlanticus	----	55,200	147,000
Ch. borealis	469,000	----	----
Ch. borealis var. *concavicornis*	3,280,000	----	----
Ch. convolutus	3,870,000	----	94,100
Ch. constrictus	703,000	----	----
Ch. decipiens	820,000	55,200	94,100
Ch. didymus	3,280,000	----	110,000
Ch. furcellatus	3,630,000	----	----
Coscinodiscus centralis	----	18,400	36,800
Rhizosolenia semispina	----	----	36,800
Rh. Shrubsolei	117,000	----	18,400
Thalassionema nitzschioides	234,000	----	----
Thalassiosira Nordenskioeldii	1,170,000	----	----
Ceratium Fusus	----	----	18,400
C. longipes	----	18,400	----
Peridinium spp.	234,000	147,000	405,000
P. depressum	----	91,000	----

TABLE 32.—May, 1934. Cells per Column.

Species Station	2186	2201	2205
Chaetoceros constrictus	11,140,000	----	----
Ch. convolutus	72,000	----	----
Ch. debilis	3,150,000	----	----
Ch. decipiens	270,000	----	----
Ch. didymus	558,000	----	----
Ch. laciniosus	72,000	----	----
Coscinodiscus centralis	18,000	----	11,100
Detonula confervacea	54,000	----	----
Melosira sulcata	216,000	----	----
Porosira glacialis	2,195,000	----	----
Rhizosolenia semispina	18,000	----	----
Thalassiosira Nordenskioeldii	18,000	----	----
Ceratium longipes	----	16,600	33,400
Noctiluca miliaris	----	----	11,100
Peridinium sp.	72,000	82,700	66,800
P. depressum	----	82,700	55,600

TABLE 33.—June, 1934. Station 2220.

Species	Depth	Cells per Liter 1 m.	40 m.	70 m.
Rhizosolenia sp.		--	45	--
Peridinium sp.		--	20	--
Acanthoica acanthifera		--	45	--
Flagellates		20	130	20
Protozoa		--	20	--

TABLE 34.—June, 1934. Station 2224.

Species	Depth	Cells per Liter 1 m.	30 m.	50 m.	80 m.
Melosira sulcata		--	--	200	--
Thalassiosira sp.		--	--	--	20
Rhizosolenia sp.		45	--	--	--
Ceratium longipes		20	--	--	--
Peridinium		--	20	20	--
Acanthoica acanthos		20	--	--	--
Flagellates		485	65	20	--
Protozoa		240	--	65	45

TABLE 35.—June, 1934. Station 2226.

Species	Depth	Cells per Liter 1 m.	10 m.	30 m.	50 m.
Chaetoceros decipiens		--	--	45	--
Ch. furcellatus		--	--	45	--
Guinardia flaccida		20	--	--	--
Melosira sulcata		45	--	420	--
Nitzschia longissima		65	--	45	--
Pinnularia sp.		--	--	45	--
Rhizosolenia sp.		45	--	--	--
Thalassionema nitzschioides		200	--	--	--
Thalassiosira sp.		20	--	420	--
Th. Nordenskioeldii		220	420	--	130
Dinophysis acuminata		65	--	--	--
D. Ovum		--	20	--	--
Peridinium sp.		45	--	20	20
P. conicum		--	400	--	--
P. depressum		20	--	--	--
P. Granii		--	640	--	--
P. Simplex		200	--	--	--
Flagellates		4840	9640	2070	90
Protozoa		1690	770	440	--

TABLE 36.—June, 1934. Station 2228.

Species	Depth	Cells per Liter 10 m.	30 m.	80 m.
Actinoptychus undulatus		--	45	--
Chaetoceros decipiens		20	110	--
Coscinodiscus excentricus		--	45	90
Melosira sulcata		--	300	--
Pleurosigma Normani		155	130	20
Thalassionema nitzschioides		--	45	--
Thalassiosira decipiens		375	155	--
Th. Nordenskioeldii		--	--	20
Flagellates		--	20	--

TABLE 37.—August, 1936.

Key: 4—dominant; 3—common; 2—rare; 1—very rare.

Species	Station 2659	2660	2663	1	3
Chaetoceros affinis	–	–	–	1	–
Ch. atlanticus	–	–	–	–	1
Ch. borealis	–	–	–	1	1
Ch. compressus	–	–	–	4	–
Ch. constrictus	–	3	–	2	–
Ch. convolutus	–	–	–	2	–
Ch. crinitus	–	–	–	1	–
Ch. decipiens	1	1	–	–	–
Ch. didymus	1	–	–	–	–
Ch. laciniosus	–	–	–	2	–
Ch. pseudocrinitus	–	–	–	3	–
Ch. teres	–	–	–	4	–
Corethron hystrix	–	–	–	1	–
Coscinodiscus centralis	–	–	–	–	2
C. excentricus	–	–	–	–	1
Guinardia flaccida	2	2	2	–	2
Leptocylindrus danicus	–	2	–	1	–
Lichmophora abbreviata	–	–	–	1	–
Navicula sp.	–	–	–	1	1
Nitzschia Closterium	–	1	–	2	4
Pleurosigma Normani	–	–	–	1	2
Rhizosolenia alata	4	4	1	–	–
Rh. calcar-avis	–	–	–	4	–
Rh. semispina	1	1	1	–	–
Rh. Shrubsolei	–	1	–	3	–
Rh. styliformis	–	–	–	4	4
Sceletonema costatum	–	–	–	–	–
Thalassiosira Nordenskioeldii	–	–	–	1	–
Ceratium bucephalum	1	–	–	–	–
C. Fusus	1	1	1	1	–
C. lineatum	1	1	–	–	–
C. longipes	2	1	–	–	–
C. macroceros	1	1	1	–	–
C. tripos	1	1	–	–	1
C. tripos var. *atlanticus*	3	1	2	1	–
C. tripos var. *subsalsum*	3	1	–	–	–
Dinophysis acuminata	1	1	–	–	–
D. norvegica	1	–	–	–	–
D. Ovum	–	1	–	–	–
Gymnodinium sp.	–	–	–	1	1
Noctiluca miliaris	1	–	–	–	1
Peridinium sp.	1	1	–	–	–
P. crassipes	2	2	–	–	–
P. depressum	–	–	–	1	1
Prorocentrum micans	1	–	–	–	–
P. Scutellum	–	–	–	1	–
Pontosphaera Huxleyi	–	–	–	1	–
Dictyocha fibula	–	2	–	–	–
Distephanus speculum	–	1	–	–	–

Comparison of the Environment and Certain Physiological Activities of Alfalfa and Prairie Vegetation*

Morton T. Fredricksen

CONTENTS

	PAGE
Introduction	641
Objectives and Procedure	642
Description of the Area	642
Soils	643
The Prairie	644
The Field of Alfalfa	645
Water Relations	646
Precipitation	646
Runoff	648
Water Content	651
Zone of Absorption	655
Discussion	655
Aerial Conditions	658
Air Temperature	658
Humidity	660
Vapor Pressure Deficit	662
Wind	663
Light	665
Evaporation	665
Soil Temperature	667
Discussion	669
Phytometers	670
Water Loss and Production of Dry Matter	674
Discussion	677
Summary	678
References	680

Introduction

This study is the second of a series on the comparison of environments and development of crop plants and native vegetation. The first (Flory, 1936) dealt with maize and upland prairie; a third, nearing completion, (Noll, 1938) is a comparison of winter wheat and native grassland. This research deals with the relative growth of alfalfa and certain of its physiological activities as compared with the vegetation of adjacent, unbroken prairie. The present paper will also complete the twenty-third year of a continuous study of the major environmental factors of air and soil in the most extensive and most productive plant formation in North America (Weaver and Himmel, 1931).

With the disappearance of the prairie, the value of a knowledge of the

* Contribution from the Department of Botany, University of Nebraska, No. 108.

original natural environment is becoming increasingly evident. Innumerable environmental changes have occurred both in the soil and above ground with breaking and cropping the land. Such fundamental factors as humidity, temperature, wind, and evaporation have all been locally modified. The soil has been changed in structure, organic matter, fertility, and in the kinds and quantity of living plant materials. During the short period of time since the destruction of the original cover that has characterized the grassland formation for thousands of years, much of the soil has been washed or blown away. The increasingly perplexing problems besetting the plant producer may more readily be understood and their solutions more intelligently ascertained when projected against the background of the original plant environment (Smith, 1932; Weaver and Flory, 1934).

The climate of the midcontinental grassland area is subject to great variations. This work was done during the most extreme drought that has ever been recorded in eastern Nebraska. It afforded an unparalleled opportunity to measure extremes of differences in the two habitats and to study the behavior of both native and crop plants under the most adverse conditions.

Objectives and Procedure

This study deals with a comprehensive comparison of the environment and certain physiological responses of native grassland vegetation and alfalfa. Environmental factors were quantitatively determined in the two habitats from May, 1935, until September, 1936, except during the season of dormancy. They included atmospheric factors of precipitation, humidity, vapor pressure deficit, temperature, wind, evaporation, and light. The soil profile was examined and hygroscopic coefficients and pH of the soil at different depths were determined. Continuous records of soil temperatures were obtained; runoff was measured, and water content was determined weekly to a depth of four feet and at monthly intervals to six feet. The physiological responses measured were rate of water loss by phytometers, and rate of growth as determined both by increase in height and production of dry matter.

Description of the Area

The prairie and field used in this study lie three miles north and one mile west of the University of Nebraska in Lincoln. They consist of a gently rolling tract of land one-half mile long, from north to south, and nearly one-half mile wide. The alfalfa field included an area 30 rods wide and one-half mile long. The land has been broken and cropped for a period of 31 years. Unbroken prairie occupies the remainder of the tract, except that the west one-half has been grazed, but only moderately, for several years. The pasture formed a buffer to the prairie which occupied a width of 20 rods throughout the full length of one-half mile. A small ravine crosses both field and prairie from east to west about one-third of the distance from the south end. The stations were established on the gentle north slope just south of the ravine. Thus, the area of both field and prairie was extensive enough to eliminate

largely the influence of neighboring habitats. The southerly winds blew over a considerable area of prairie or alfalfa, respectively, before encountering the instruments and plants at the respective grassland or field station. Thus, normal temperatures, humidity, and evaporation for each microclimate were attained (Fig. 1).

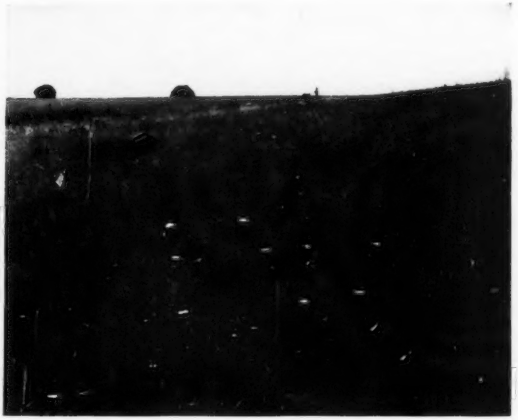


Fig. 1. The prairie station looking east on August 2, 1935. The bluestem grasses are 15 to 24 inches tall and almost conceal the framework about the prairie phytometers in the foreground; field and stacks of alfalfa in the distance.

Soils

The soil is Carrington silt loam, a type common and extensive in eastern Nebraska. It has the profile of a mature soil. The A horizon is dark in color, fairly rich in humus, and extends to a depth of about 18 inches. The upper portion is disturbed in the field by repeated cultivation. At 12 inches depth the soil becomes lighter in color, and the silty clay loam of the surface 12 inches grades into clay. The B horizon extends about 18 inches deeper. It consists of a yellowish clay which is plastic when wet but very hard when dry. The prismatic structure is well developed and during drought there is great shrinkage among the vertical prisms. The C horizon occurs at about 32 inches depth. While there is an entire absence of coarse sand to this depth, the sand component consisting wholly of very fine sand, in the C horizon the clay gradually becomes intermixed with an increasing proportion of coarser sand. Between 5 and 13 feet, layers of sand and clay are intermixed. No lime layer is found at any depth in this Prairie soil, but the Chernozem with a well marked lime horizon occurs only 20 miles westward.

The hygroscopic coefficients of the soil at the several depths to 6 feet are given in Table 1, where the pH is also recorded.

TABLE 1

Hygroscopic coefficients of soil and subsoil and pH to 6 feet in prairie and field.

Depth feet	Prairie Hygro. coef.	Field Hygro. coef.	Prairie pH	Field pH
0.0-0.5	8.8	10.4	6.0	5.6
0.5-1	9.6	12.5	6.0	5.8
1 - 2	10.8	13.2	6.2	6.0
2 - 3	10.0	12.0	6.9	6.0
3 - 4	10.3	12.0	7.8	6.5
4 - 5	10.5	11.6	7.8	6.5
5 - 6	10.6	11.2	7.5	6.8

Hygroscopic coefficients of subsoil

Depth, feet →	7	8	9	10	11	12	13	14	15
Prairie	5.0	4.1	3.1	2.1	1.8	2.7	2.0	1.8	2.4
Field	6.0	5.8	5.3	6.3	5.0	4.0	3.3	2.5	3.6

The hygroscopic coefficients are consistently lower at all depths in the prairie, indicating the soil is somewhat coarser in texture. Below 6 feet, the soil is principally sand as is shown by the abrupt decrease in the hygroscopic coefficients. Both soils are slightly acid in the first 3 feet (but more acid in the field) due to the leaching of the carbonates throughout the centuries. The mildly acidic conditions prevailed in the field to the depth of sampling at 6 feet. These conditions are fairly representative of upland soils of eastern Nebraska, where liming the soil is rarely practiced.

The Prairie

The prairie vegetation is of the upland mid-grass type. The chief dominants are little bluestem *(Andropogon scoparius)*, which alone constitutes about 60 per cent of the vegetation, needle grass *(Stipa spartea)*, prairie dropseed *(Sporobolus heterolepis)*, June grass *(Koeleria cristata)*, and side-oats grama *(Bouteloua curtipendula)*. All but the last are bunch grasses. Big bluestem *(Andropogon furcatus)* is dominant in the ravines, and bluegrass *(Poa pratensis)* forms a 3 to 10 per cent mixture throughout. In addition there is an abundance of forbs. This little-bluestem type has been fully described by Weaver and Fitzpatrick (1934). This prairie has not been grazed for a period of at least 40 years, and probably only moderately since the disappearance of the buffalo. It is used for the production of hay and mowed annually in late summer or fall, except in years of extreme drought.

During the year just preceding these studies (1934) there occurred an extremely severe drought during the growing season, indeed, up to that time the greatest ever recorded in the prairie region (Weaver, Stoddart, and Noll, 1935). This resulted in marked changes in the normal composition of the prairie (Weaver and Albertson, 1936). Chief among these was the high mortality of little bluestem, many bunches being entirely killed and others represented by a mere fringe of dwarfed stems. June grass, needle grass, and bluegrass also suffered greatly. Losses were severe among grasses of the understory, notably *Panicum scribnerianum* and *P. wilcoxianum*, as they were also

among forbs (*Antennaria campestris, Viola pedatifida,* etc.) of similar dependence upon the mid grasses for protection from too great insolation and too low humidity. Big bluestem and deeply rooted forbs were not greatly affected.

The excellent conditions for growth in spring and early summer following the drought resulted in vigorous development of the survivors, rapid reseeding, and invasion by rhizomes of the bared areas. Hence, following the drought of 1934, much of the area formerly occupied by little bluestem was taken over by June grass and needle grass. Prairie dropseed became much more abundant as did also side-oats grama. Even bluegrass spread rapidly from the scattered, well shaded areas where it had not succumbed to drought.

The Field of Alfalfa

The field for alfalfa had been under cultivation for 31 years. The three preceding crops were wheat. Common alfalfa was drilled in rows 4 inches apart on September 8, 1934, after the wheat stubble had been plowed and repeatedly harrowed in preparing a good seedbed. A rainfall of an inch, on September 3, resulted in excellent germination, the soil having been brought into favorable contact with the seed by the use of a roller. So far as is known, alfalfa had never before been grown in this field. Counts of the individual plants (crowns) over a representative area of 13.3 square feet were made in order to approximate the number of plants per acre and to ascertain the number that finally survived. These data over a period of two years are summarized in Table 2.

Fig. 2. The alfalfa station during the latter part of July, 1935, showing the typical field conditions around the phytometers which are located at the distant end of the trench used for weighing. The doors of the trench are closed. Elevated and surface atmometers at the left.

TABLE 2

Number of alfalfa plants per unit area from 1935 to 1937.

Date	Plants per 13.3 square feet	Plants per acre	Percentage survival
July 16, 1935	495	1,617,566	100
August 13, 1935	421	1,375,748	85
September 11, 1935	382	1,248,303	77
June 15, 1936	257	839,827	52
August 15, 1936	192	627,419	39
July 16, 1937	183	598,009	37

The writer knows of no similar data with which these may be compared. Losses of 46 to 82 per cent have been found in the growth of the first crop of alfalfa after root injury produced by low temperatures (Tysdal, 1934). It is believed from the appearance of the field that such mortality represents perhaps the usual loss as a result of competition of the seedlings for the factors of the habitat, losses due to winterkilling, etc. (Fig. 2).

Water Relations

Water is a most important factor, and in this region usually the limiting one, in the development of vegetation. The amount of precipitation largely determines the availability of soil moisture but many factors intervene to decrease its effectiveness. Much of the rainfall is intercepted by the crowns of plants and evaporates. The intensity, duration, distribution, and nature of the precipitation as well as the slope of the land and the structure of the soil affect the available soil moisture. A cover of vegetation decreases runoff, but the vegetation, through transpiration and growth, also depletes the moisture reserves of the soil. Rainfall efficiency decreases with high air temperatures and low humidities because of excessive evaporation. The growth of native vegetation, particularly prairie grasses, increases soil porosity and adds humus through the growth and death of roots and rhizomes and the incorporation of decaying aboveground parts. This increases the water absorbing and retaining properties of the soil. Cultivation decreases soil organic matter, which tends toward soil compaction, thus decreasing absorption of water and increasing runoff. Many factors thus affect the water relations of vegetation. In semi-arid regions a good crop yield may result from only two or three inches of excess moisture, while a similar decrease in rainfall may be the cause of crop failure. During extreme drought, an inch or two of effective rainfall becomes a factor entirely out of proportion to the same amount of moisture falling in a more humid climate.

PRECIPITATION

The mean annual precipitation at Lincoln over a period of 60 years is 27.98 inches. Its distribution is of the Great Plains type, over 75 per cent occurring between April 1 and September 30. This type of precipitation is favorable to the growth of grasses, but, due to the high temperature, losses by evaporation from the soil are greatly increased. However, periods of drought are likely to occur at any time during the growing season. Their

duration is often two or more weeks with .1 inch or less of rainfall. During the warmer months much of the precipitation occurs as torrential thundershowers which may result in considerable runoff and erosion. Showers of .3 inch or less are of little value in increasing soil moisture. From 60 to 65 per cent of the rainfall occurs at night. This favors decreased loss by evaporation. Less than one-tenth of the moisture falls during the three winter months, chiefly as snow. Much of the snow is evaporated into the air without moistening the soil, or it may be swept by high winds into depressions and thus contribute but little to the water content of the soil.

Rainfall was measured by means of a standard rain gage installed midway between the stations in alfalfa field and prairie. Since soil moisture reserves were low at the beginning of the growing season of 1935, due to the extreme drought of the preceding year, growth of vegetation depended almost entirely upon current rainfall.

The rainfall of May (5.44 inches) exceeded the mean by more than an inch; throughout June and July it was nearly normal (Table 3). Drought was experienced during August, with a rainfall deficiency of 1.87 inches, when none of the light showers exceeded .36 inch. During the remainder of the year, the precipitation was slightly above normal. The season of 1935 was thus favorable to growth, except during August. The total rainfall deficiency was only 2.63 inches.

TABLE 3

Precipitation during 1935 and 1936, and mean precipitation for the past sixty years, at Lincoln, Nebraska.

Time	Jan.	Feb.	Mar.	Apr.	May	June		
1935	.30	.87	.96	1.33	5.44	3.81		
1936	1.64	.68	.18	2.29	1.95	1.13		
60 Years	.64	.99	1.27	2.53	4.08	4.32		
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	
	3.83	1.70	2.71	2.23	1.87	.30	25.35	
	.08	1.63	3.38	.18	.06	.88	14.09	
	3.85	3.57	2.98	1.88	1.07	.80	27.98	

Precipitation during 1936 was only 50 per cent normal, and was the least on record with the single exception of the year 1894. The amount, however, was practically the same as that of the very dry year, 1934. January and September were somewhat wetter than normal; rainfall in April was near the mean; all other months were dry. July of this year was the driest July on record. The summer as a whole was the hottest and driest ever recorded in Nebraska. The precipitation was only 24 per cent normal. From May 9 to August 21 the rainfall of individual storms varied from .03 to only .33 inch. Only 0.1 inch fell from July 1 to August 4. Rainfall deficiency for the year was 13.89 inches. Growth of vegetation was rapid during May, but the development of both alfalfa and native plants was checked the latter half of June, after which general deterioration occurred until September.

Runoff

The water which runs off is lost to the soil and cannot be used by the crop. Rainfall interception, runoff, and evaporation from the soil all reduce rainfall efficiency. The large amount of precipitation (25 to 80 per cent) intercepted by both native and cultivated vegetation has only recently been determined in the prairie region (Clark, 1937). Runoff is usually the most serious since not only is considerable moisture lost to the crop but also soil nutrients are carried away in the runoff water. The topsoil is gradually eroded, certain amounts of organic matter are removed, soil fertility is decreased, and the excellent structure of the soil destroyed.

The plot method of measuring runoff was used in comparing the water lost from the alfalfa field and prairie. Two parallel plots were selected in the field and two in the prairie. They were on a five degree slope, and not more than 50 feet apart. The plots were 33.3 feet long and 3 feet wide. They were surrounded on three sides by planed boards, 6 inches wide and seven-eighths inch thick, placed on edge in the soil to a depth of 3 to 4 inches and held firmly by stakes, driven into the soil just outside the area, to which the boards were nailed. All joints were water tight, and the soil outside the plot was tamped firmly against the boards. Galvanized iron interceptometers, 3 feet long, 8 inches wide, and 18 inches deep, were installed at the lower end of the plots at right angles to the slope. The excavation for these was 10 inches wide, 18.5 inches deep, and just long enough to receive the container, with the front (upper) wall perpendicular and smooth. The front side of the interceptometer was then fitted tightly against this wall with the upper edge about .5 inch below the soil surface. Soil was tightly tamped against the entire back wall of the container, thus holding it firmly in place (Weaver and Noll, 1935).

Each interceptometer had a sloping metal roof, constructed so that no water could enter the container except that from the runoff plot. Water running down inside the plot found its way into the interceptometer, entering under the top which was about five-sixteenths inch above the soil surface. The accumulated water was removed and measured each day or after every rain. Interceptometers that were found to be too small to hold all of the runoff water were supplied with a spout 0.5 inch in diameter and 2 inches long soldered to an opening in the back about an inch from the top. This was connected by rubber tubing to a covered overflow tank sunk in the soil just back of the interceptometer. Where the muddy water indicated soil erosion, the contents of the containers were transferred to settling tanks. The clear water was later siphoned off, the sediment air dried, and the quantity of eroded soil determined.

From April 7 to November 26, 1935, the rainfall totaled 23.7 inches.* The average runoff from the alfalfa plots was 14.3 per cent; from the prairie it was 1.35 per cent. Thus, 10.5 times as much water was lost by runoff from the alfalfa field as from the prairie.

* Rainfall data in relation to runoff and water content of soil are from the readings of the rain gage at the station and not from the Weather Bureau at Lincoln.

Runoff during 1936 was small, owing to unusually low precipitation. Only 11.21 inches of rain fell from March 15 to October 4. From the middle of May to early September, no shower exceeded .68 inch. The average runoff in the field was 4.9 per cent and in the prairie .45 per cent. Thus, the alfalfa field lost 10.8 times as much water by runoff as the prairie. Runoff resulting from selected individual rains for both years is given in Table 4.

TABLE 4

Runoff from individual rains in alfalfa field and prairie.

Date	Rainfall, inches	Height of alfalfa, inches	Height of grasses, inches	Percentage of runoff	
				Field	Prairie
1935					
May 27	.54	8	6	33.4	.64
June 3	.63	10	7	87.2	2.40
July 4	1.18	7	16	30.8	.46
September 2	2.07	8	17	24.3	.41
1936					
April 28	1.73	4	3	11.1	1.90
September 4	1.17	4	6	13.8	.38
September 26	1.87	6	6	8.4	.53

The data show clearly the greater amount of runoff in the field, where an average of 29.8 per cent of the rainfall was thus lost, compared to .96 per cent in the prairie. It is of interest to note that a rain of small amount when falling rapidly may result in greater runoff than a gentle but heavier rainfall. For example, .63 inch of rain on June 3, 1935, resulted in 87.2 and 2.4 per cent runoff in the alfalfa field and prairie, respectively. On September 2, 2.07 inches preciptation produced only 24.3 per cent runoff in the field and .41 per cent in the prairie.

Although each rain in 1936 was of greater intensity than those of 1935,* yet the runoff was much less. The difference, therefore, must be attributed to the greater efficiency of the two-year-old alfalfa in decreasing the force with which the water reached the soil and in preventing runoff.

Because of the extreme drought, the plots were also watered artificially and the runoff determined. Artificial watering has numerous advantages over natural rainfall. Water can be applied at any desired rate, the behavior of the soil surface in relation to water intake may be directly observed, the time when runoff or erosion begins determined, and the relative turbidness or clearness of the water observed. For this experiment one plot in the alfalfa and one in the prairie were used on July 20, 1936. The grasses in the prairie averaged only 8 inches in height, although *Amorpha canescens* and certain other forbs were slightly taller. The density of the foliage cover, however, was reduced by wilting and folding of the leaves. Hence, the soil was less well protected than usual. Although the soil of the two-year-old alfalfa field was extremely dry, no cracks were present. The surface soil was covered with

* Data obtained from the Weather Bureau at Lincoln, Nebraska, three and one-half miles distant.

the dried stubble from the first cutting of hay and a very small amount of second growth which did not exceed 2 inches in height. Weeds were few.

Water was hauled in 55-gallon, steel barrels and sprinkled uniformly over the 100-square foot enclosure. This was done by five men, each watering an area of 20 square feet. The results are given in Table 5.

Two days after the application of the 4 inches of water, when field carrying capacity had been reached, soil sampling showed that the moisture had penetrated to a depth of only 10.5 inches in the alfalfa plot but to 18 inches in the prairie. While no runoff occurred in prairie, in the field, as each succeeding inch of water was added, it increased greatly until the last inch was applied. It decreased only slightly upon application of the fourth inch. Soil was eroded only after the first hour of the experiment.

It should be noted that the rows of alfalfa ran with the slope. It would be of much interest to ascertain runoff on similar slopes where the rows ran with the contour. The natural irregular distribution of prairie vegetation, where, however, only 10-15 per cent of the surface is occupied by the bases of plants, is very advantageous in decreasing runoff.

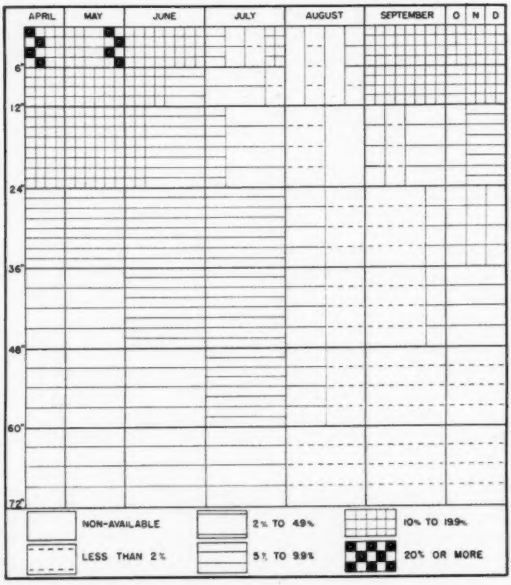


Fig. 3. Available water content of soil in the prairie at the several depths to 6 feet during 1935. (Precipitation as in Fig. 4).

TABLE 5

Runoff resulting from the application of 4 inches of water to praire and two-year-old alfalfa.

Station	Time	Water, inches	Percentage of runoff	Soil eroded, pounds per acre	Remarks
Prairie	7:30-8:00	1	0.0	0.0	All water readily absorbed. No puddling of surface soil.
	8:00-8:30	1	0.0	0.0	
	8:30-9:00	1	0.0	0.0	
	9:00-9:30	1	0.0	0.0	
Alfalfa	9:30-10:00	1	1.4	0.0	Runoff began after 21 minutes. Water ran from upper end of plot after 37 minutes.
	10:00-10:30	1	17.6	0.0	
	10:30-11:00	1	26.4	46.4	
	11:00-11:30	1	25.4	45.7	

WATER CONTENT

Duplicate soil samples for moisture determinations were taken weekly to a depth of 4 feet in both prairie and field, and once each month to a depth of 6 feet. These were secured with Briggs' geotomes. The samples were

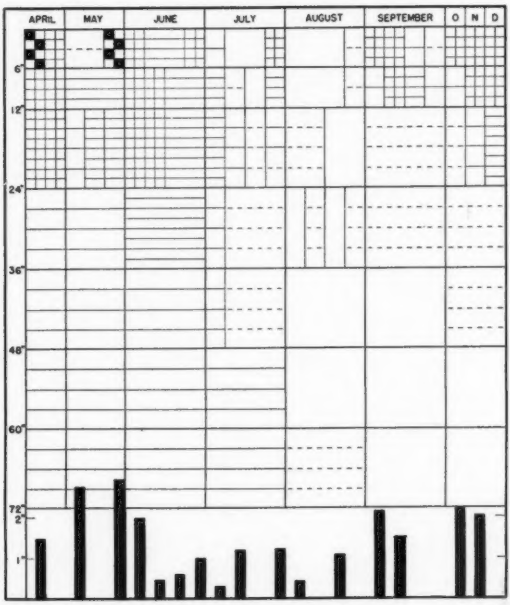


Fig. 4. Available water content of soil in the alfalfa field at the several depths to 6 feet during 1935; also weekly precipitation in inches. (Legend of available water as in Fig. 3).

placed in air-tight cans, weighed immediately, and oven-dried at 110° C. They were then reweighed, and the amount of moisture calculated as a percentage of the dry weight of the soil. Available water is considered as the percentage of water content in excess of the hygroscopic coefficient (Alway, 1913; Weaver and Clements, 1938).

Available soil moisture was greater in the prairie at all depths, and especially at the lower sampling levels, during both seasons. It ranged from less than 2 to over 20 per cent in the first two feet of soil during May and June, 1935, as a result of rains of 5.8 inches during May and 4.12 inches during June (Figs. 3 and 4). Water content of soil varied from 2 to over 8 per cent in the deeper layers in both prairie and field during these months. By the last week of June, more than 12 per cent was available in the first six inches of soil in each plot and over 6 per cent in the second six inches. The prairie contained over 7 per cent in the second foot while the alfalfa soil had 2 per cent less. The subsoil held from 2 to 5 per cent; the prairie having slightly more available moisture.

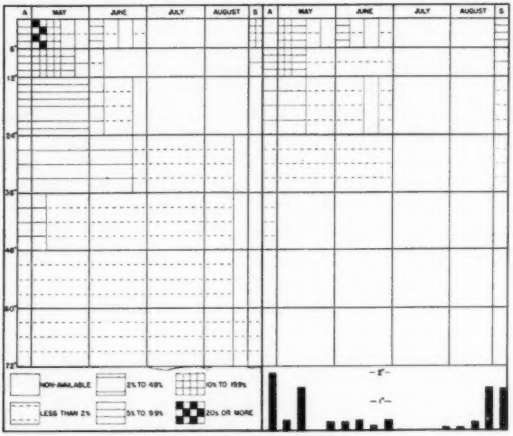
Although three inches of rain fell during July, by the middle of the month there was no water available in the first six inches in the alfalfa field, and none in the second six inches during the third week. Water was available at all depths in the prairie during this period, even the fifth foot having increased in moisture content. June and July was the period of maximum subsoil moisture in both habitats; this resulted from the heavy early summer precipitation. By July water had penetrated to 5 feet in the prairie. Absorption and transpiration in the field were so rapid, however, that subsoil moisture was not replenished.

August yielded only 1.45 inches of rain. No moisture was available in the first foot of prairie soil during the first and third weeks, and none in the second during the last two weeks. The prairie subsoil contained less than 2 per cent available moisture in the fifth and sixth foot. During the first three weeks no water was available in the first foot of field soil. The plants, likewise, had exhausted all available water in the second foot during the last half of the month. The third foot of soil had only 1 per cent or less available moisture; there was none in the fourth and fifth foot, and less than 2 per cent in the sixth.

September rainfall was in excess of 3.5 inches. The rains occurred early in the month and increased the available soil moisture to over 10 per cent in the first foot of prairie soil but only the first six inches in the field. In the prairie, a small amount of available water occurred in the fourth, fifth, and sixth foot, but none in the field. During the three following months, as a result of more than 4 inches of rain, water was available at all depths in the prairie; there was more than 10 per cent in the first foot, over 5 per cent in the second, 2 to 5 in the third and fourth foot, but less than 2 in the fifth and sixth. Moisture was available in the first four feet of soil in the alfalfa field, with over 10 per cent in the first foot, 2 to 9 in the second, but less than 2 per cent in the third and fourth, while at greater depths of sampling no moisture was available. There was no change in the subsoil moisture after

the close of the growing season. Thus, the prairie constantly maintained a greater supply of water at all depths than did the alfalfa field.

The season of 1936 was decidedly less favorable for growth. Late winter and early spring were dry (Table 3). Rainfall in April was 2.3 inches. This increased the water content of the surface 6 inches of prairie soil to 20 per cent and that of the field to 10 per cent (Figs. 5 and 6). Since the rainfall



Figs. 5 and 6: Fig. 5 (left). Available water content of soil in the prairie at the several depths to 6 feet during 1936. (Rainfall as in Fig. 6). Fig. 6 (right). Available water content of soil in the alfalfa field at the several depths to 6 feet during 1936; also weekly precipitation in inches. (Legend of available water content as in Fig. 5).

of May was only about 2 inches, absorption exceeded replenishment of soil moisture and the amounts available were greatly reduced. Thus, in the prairie late in May available moisture contents at the several depths to three feet were about 1, 3, 5, and 3 per cent, respectively, but those in alfalfa 0, 1, 1, and 1 per cent.

June was likewise dry; only 1.1 inches of rain fell. By the end of the month less than 2 per cent moisture was available in each habitat in the first 3 feet.

July was without effective precipitation; 1.6 inches were recorded for August. No water was available in the first two feet of the prairie, and by August 19 the first 5 feet were below the hygroscopic coefficient. In the field, no water was available at any depth to 7 feet during this entire period. This marked the low point in moisture reserves in the prairie during the two years.

On September 9, after nearly 1.5 inches of rain, over 2 per cent of water was available at each station in the first foot of soil. In the prairie, however,

none was available at greater depths to the sixth foot. Here a small amount of moisture was found at all times during the season. The alfalfa field contained less than 2 per cent available water in the second and third foot, but none at greater depths. In fact, no water was available at any time in the fifth and sixth foot of soil.

A comparison of water content of soil week by week at the several depths reveals the following facts: In the first three sampling levels, *i.e.*, to 2 feet in depth, water content was greater (at one or more depths) 31 times in the prairie but only 3 times in the field, during 1935. At a depth of 2 to 4 feet, the water content was greater 35 times in the prairie and was never exceeded by that in the field. At greater depths (by months, Figs. 3 and 4) the prairie exceeded the field 7 times, but not a single reverse condition maintained. In 1936 the prairie soil was wetter 17 times in the upper levels; alfalfa only 5 times. From 2 to 4 feet depth, the grassland had a higher water content in 29 instances, alfalfa in only 1. At greater depths the prairie was wetter 12 times.

The great depth of root penetration of even young alfalfa is well known (Weaver, 1926). Likewise, many prairie forbs have been shown to extend their root systems to depths of 8 to 20 feet, although that of the deepest of upland grasses (big bluestem) seldom exceeds 7 feet. Consequently, soils were sampled in both prairie and field to determine the available moisture at depths beyond those from which samples were regularly taken. The sampling was done late in July, 1936. By means of appropriate extensions attached to the Briggs' geotome and a hammer raised and lowered by an improvised derrick, samples were taken in triplicate at each level from 5 to 15 feet. The geotome was withdrawn from the soil by means of a jack. The three sets of samples were obtained 20 to 30 feet distant at each station. The two sampling stations were only 40 to 50 feet apart (Table 6).

TABLE 6

Percentage available soil moisture content to a depth of 15 feet.

	Prairie		Alfalfa	
Depth, feet	Hygroscopic coef.	Available moisture	Hygroscopic coef.	Available moisture
5	10.5	.9	11.6	.0
6	10.6	.3	11.2	.0
7	5.0	.8	6.0	.3
8	4.1	1.1	5.8	.5
9	3.1	1.1	5.3	.9
10	2.1	.9	6.3	1.1
11	1.8	.9	5.0	1.5
12	2.7	1.6	4.0	1.9
13	2.0	.9	3.3	2.0
14	1.8	1.1	2.5	1.5
15	2.4	2.1	3.6	2.1

Very little available moisture was present at either station to a depth of 15 feet. The prairie subsoil had at least slightly more than twice as much moisture as the alfalfa at all levels from the fifth to the ninth foot. From

the tenth foot downward, however, the field subsoil had slightly more water, due to a finer texture and consequently greater water retaining power than in the prairie, as is indicated by the hygroscopic coefficients. The prairie subsoil consisted of sand of medium texture in the ninth foot, but was somewhat coarser at greater depths. The field subsoil also consisted of sand, but this was finer sand.

Zone of Absorption

In any study of soil moisture relations, the depth at which water is removed by absorption is of fundamental importance. Hence, when the plants were nearly two years old (August 2, 1936) root depth and distribution were investigated. A trench 10 feet long and 3 feet wide was dug near the station, finally to a depth of 14 feet. The crowns of the plants just below the soil surface were 1 to 1.5 cm. in diameter. The taproots of the alfalfa plants grew nearly straight downward. Below the crowns and to a depth of 1.5 feet, the roots were well supplied with an abundance of small laterals, usually less than a millimeter in diameter. The taproots tapered rather rapidly, so that at a depth of 20 inches the diameter seldom exceeded 5 mm. Through the B horizon the roots followed the crevices between the soil prisms. They were well supplied with small laterals less than an inch in length, which were quite evenly distributed over the surfaces of the prisms. At a depth of 4 to 6 feet the diameter of the taproot was only 1 mm. or less and below 10 feet .5 mm. Many roots ended at a depth of 12 feet. The longest extended to a layer of moist, bluish clay at a depth of 13 feet and 2 inches.

The alfalfa roots exhibited a decided tendency to follow earthworm burrows or crevices in the subsoil. Oftentimes 5 to 8 small roots were found entwined as they followed such openings through the soil.

Discussion

Soil moisture was continuously available at all depths in the prairie during the growing season of 1935, excepting two brief periods during August when it was below the hygroscopic coefficient in the first and second foot. Alway, McDole, and Trumbull (1919) found the surface 2 to 3 feet of upland prairie soil at Lincoln, Nebraska, dried to the point of unavailable moisture on only three occasions in the six years 1906 to 1912. From 1909 to 1912 the moisture content in the first foot of the prairie soil was reduced to the hygroscopic coefficient only once. From investigations in the prairie, including weekly soil sampling over a period of 13 years (1915 to 1928), Weaver and Himmel (1931) determined that during seasons of approximately normal rainfall, available soil moisture was always present in prairie soil.

During the greater part of the drought year of 1936, however, less than 2 per cent of available water was present in the first six feet of prairie soil, and none in the first five feet during the latter part of August. Similar results have been reported by Weaver and Albertson (1936) for the drought year of 1934. As the alfalfa grew and extended its roots, the soil became completely exhausted of moisture beyond a depth of four feet during the latter

part of the first season. This subsoil moisture was never regained, and the soil above 4 feet became much drier during the following season. Slightly more moisture was present at all times in the prairie, especially in the deeper layers, during both years. This investigation shows that alfalfa exhausts the soil of moisture more completely and to greater depths than does native vegetation. It begins growth a few weeks earlier than prairie in spring, grows vigorously after each cutting, and continues growth somewhat later in fall. This continuous, rapid growth of alfalfa creates a constant demand for very large quantities of water.

Alway (1913), working in northeastern Nebraska, ascertained that subsoil moisture was drawn upon to a depth of 33 feet in a ten-year-old field of alfalfa. Further experimental studies confirm the fact that alfalfa depletes the soil moisture to great depths. Kiesselbach, Anderson, and Russel (1934), working at Lincoln, found that land cropped to alfalfa during a period of six years contained an average of only 2.2 per cent available moisture to a depth of 15 feet. Similar soil cropped to bromegrass for the same period yielded 7.4 per cent available water. On land not previously cropped to alfalfa, no moisture was present in the first 15 feet after this crop had grown four years. Five years of fallowing failed to restore the moisture removed below a depth of 14 feet by previous cropping to alfalfa.

These same investigators (1929), working at Lincoln, found that two-year-old alfalfa drew upon subsoil moisture to a depth of 25 feet, and alfalfa in a six-year-old meadow to 33 feet. The average moisture content between 5 and 15 feet in two-, three-, and six-year-old alfalfa fields had been reduced 9.4, 10.6, and 11 per cent, respectively, below that in adjoining cultivated land. A six-year-old meadow reached its greatest productivity during the third year. Their computations indicate that approximately 27 inches of rainfall are required annually to supply the transpirational needs of an alfalfa meadow during the second to sixth years of its growth. These computations were based upon an average water requirement of 858 pounds of water to produce a pound of dry matter, and the fact that 6 per cent of soil moisture is equivalent to an inch of rainfall. The latter was determined from the volume-weight of the soil to a depth of 10 feet. Very little moisture had accumulated beyond the seventh foot in a well established upland field of alfalfa after the land had been plowed and cropped to cereals for 15 years. The average increase in moisture content from 5 to 35 feet was only .4 per cent. At this rate approximately 225 years would be required to restore subsoil moisture removed by 6 years of cropping to alfalfa. The yield on land previously cropped to this legume was only 55 per cent as great as that of an adjacent meadow where alfalfa had never grown. In alfalfa fields at Lincoln, Nebraska, the amount of moisture was reduced to within 2.5 per cent of the hygroscopic coefficient during 1909 to 1912 (Alway, McDole, and Trumbull, 1919).

Duley (1929), working at Manhattan, Kansas, found that in fields of alfalfa subsoil moisture was reduced to a low point and remained almost

constant. When an eighteen-year-old field was broken in June and fallowed until August both the soil and deep subsoil gained rapidly in moisture, while other land in crops made no gain. Mean annual precipitation at Manhattan is 4.1 inches greater than at Lincoln. From these data it may be concluded that the effectiveness of fallow in restoring depleted subsoil moisture varies with the rainfall.

The numerous advantages of alfalfa as a soil builder and a nitrogenous forage are offset in semiarid climates by its depletion of subsoil moisture. During periods of drought this should be carefully considered since profitable alfalfa production is not possible where only a single crop is secured annually by depending on an insufficient yearly rainfall. Alfalfa continues to deplete the subsoil of its moisture under these conditions and restoration of the water is not possible under subsequent continuous cropping. Areas having more than 27 inches annual rainfall or lowlands with a moderately shallow water table and an inexhaustible supply of ground water are the most profitable and permanent regions for alfalfa production. Climax prairie vegetation, on the other hand, is in nearly complete adjustment with the climate and environment of eastern Nebraska. Thus, earlier studies and this investigation show that during seasons of normal rainfall there is always water available in prairie, except for short periods in the surface soil. When unusual conditions of drought deplete soil moisture to greater depths, it is rapidly restored without the loss of a crop when normal rainfall occurs, while fallowing is necessary and often ineffective in a field of alfalfa.

During the growing seasons of 1935 and 1936, the prairie was nearly 11 times as effective in preventing runoff as the alfalfa field. For the two years an average of only .9 per cent of the rainfall was lost by surface runoff in the prairie but 9.6 percent from the field. This was due largely to the greater porosity of the prairie soil. It contained a higher percentage of organic matter, which has a high water-holding capacity and produces a more porous soil structure. The many fine roots of grasses spreading throughout the soil and subsoil create minute openings through which the water may pass. Weaver, Hougen, and Weldon (1935) found that pore space occupies over 50 per cent of the volume of prairie soil. The prairie has a more continuous and more complete covering of vegetation than the field. The dead stems and leaves that accumulate on the surface form numerous dams and terraces which tend to hold the water until it seeps into the soil.

Fields that have been under cultivation for only 3 to 7 years lost 6.5 per cent of their organic matter compared to adjacent virgin prairie. After about thirty years the soil seems to attain a new level of organic matter 25 to 30 per cent lower than that of the original prairie (Russel, 1929). The loss of organic matter is serious because it is an important source of nitrogen. Moreover, loss of organic matter greatly decreases the water-holding capacity of the soil as well as destroying good structure and tilth. The addition of organic matter alone to cultivated soils, moreover, will not restore their original granulation and fibrousness. This is accomplished only by the fine, fibrous, branching root systems of the grasses. When land is in grass, granulation and

fibrousness are increased far out of proportion to the amount of organic matter added (Russel, 1929). Forsling (1931) found that where the density of the vegetation increased from 16 to 40 per cent of a complete cover, and with the coming in of plants with more extensive and more fibrous root systems, the rainfall surface runoff was reduced 64 per cent on range lands and the rainfall erosion 54 per cent.

That grass is highly efficient in preventing or retarding runoff is well known. Miller and Krusekopf (1932), working at Columbia, Missouri, over a period of 14 years, with plots having a slope of 3.68 per cent, found the surface runoff as follows: 12 per cent from bluegrass sod, 13.8 per cent from a rotation plot, 23.3 per cent from continuous wheat, 29.4 per cent from continuous corn, and 30.7 per cent from land plowed 4 inches deep and kept in fallow. Free's studies in Iowa (1936) show the runoff to be 5.5 surface inches more from continuous corn than from bluegrass sod.

Summarizing, when the organic matter is greatly depleted in cultivated fields the soil becomes poorer in structure, less porous, and water cannot penetrate as readily. Fewer roots are present to bind the soil. A larger amount of bare surface is exposed to the beating of the rain drops which throws the fine soil particles into suspension. When the muddy water penetrates the soil, these clog the minute passageways, hindering the intake of more water and causing runoff and erosion to be greatly accelerated (Lowdermilk, 1930).

Aerial Conditions

Vegetation is constantly exposed to changing environmental factors. Chief among these are temperature, humidity, wind, light, and evaporation. All are subject to more rapid fluctuations than the factors of the soil. During periods of drought the aerial conditions become extreme and the several factors then show their maximum severity.

Air Temperature

Continuous records of air temperature and humidity were secured by means of Friez' hygrothermographs housed in well ventilated, rainproof, wooden shelters of the Weather Bureau type. The sensitized portions of the instruments were about 5 inches above the soil surface. The hygrothermographs were checked frequently, but extreme care was exercised so that the surrounding vegetation suffered minimum disturbance. The average day temperatures from May until October were secured from the weekly record sheets by adding the temperatures of each 2-hour period from 6 a.m. to 8 p.m. inclusive, and dividing by the number of periods. Those of the night, from 10 p.m. to 4 a.m. inclusive, were added in like manner and divided by 4. From August 15 to October 1, however, the day temperatures included only the 6 a.m. to 6 p.m. readings inclusive, and those of the night the remainder.

Temperatures increased gradually during 1935, from June 24, after the first cutting of the alfalfa, until average day maxima of 109° F. in the prairie and 104.7° F. in the alfalfa were attained. This was during the second week of August (Fig. 7). From July 10 to September 25, the period

of greatest variation between the two stations, average day maximum temperatures were 2° to 5° higher in the prairie. Cutting of the alfalfa on August 2 had little noticeable effect upon the general temperature relations. During July and August the prairie grasses exceeded the alfalfa in height by 5 to 10 inches. This resulted in less air movement among the grasses; hence the instruments recorded slightly higher temperatures. Average day maximum temperatures were 2° higher in the prairie during the entire season.

Average day temperatures by weeks were 1° to 3° higher in the prairie from July 10 to September 4. Average day minimum temperatures were

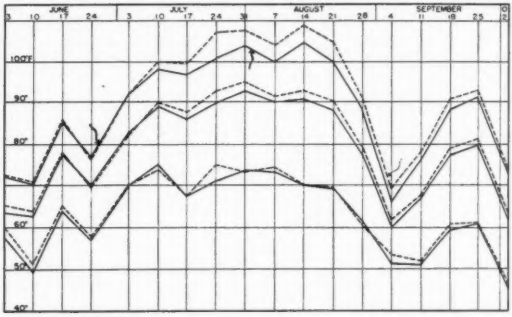


Fig. 7. Average day air temperatures by weeks in the alfalfa field (solid lines) and prairie (broken lines) during the growing season of 1935. Upper graphs, maximum temperatures; middle lines, average temperatures; and lower graphs, minimum temperatures. Dates of cutting alfalfa are indicated by heavy arrows; date of mowing prairie, by light arrow.

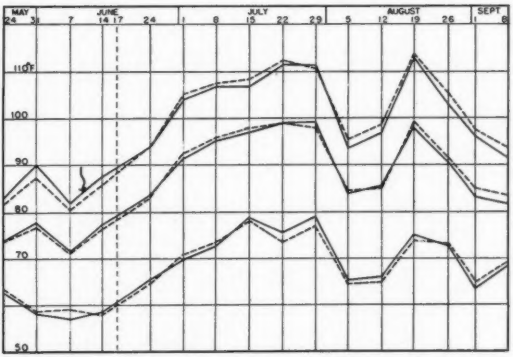


Fig. 8. Average day air temperatures by weeks in the alfalfa field (solid lines) and prairie (broken lines) during 1936. Upper graphs, maximum temperatures; middle lines, average temperatures; and lower graphs, minimum temperatures. Date of cutting alfalfa is indicated by arrow.

practically identical in the two habitats. The night temperatures followed the seasonal trends and were more nearly the same at the two stations than day temperatures. Thus, no significant differences were found in the air temperature of the two habitats.

Day temperatures at the two stations were almost identical throughout the growing season of 1936 (Fig. 8). The height of the vegetation was nearly the same and variations between the two stations were even less than during 1935. Temperatures increased gradually from June 7 until average day maxima of 114° in the prairie and 112.5° F. in the alfalfa were attained the week ending August 19. A maximum of 123° F. was reached in the prairie on July 17. It was 2° lower in the field. Such high temperatures, especially during times of drought, are very harmful to many crop plants. The average day maximum temperature was over 110° in each habitat for the last two weeks of July. From June 25 to August 26, during the warmest part of the season, it was 106.6° in the prairie and 105.3° in the field. The average day temperatures for the season were very nearly the same. Night temperatures were always slightly higher in the alfalfa. The higher temperature of the field soil may have had an effect on the air temperature 5 inches above the surface. Thus, temperature relations were nearly the same in both habitats.

Humidity

A generally inverse relationship exists between the relative humidity of the air and transpiration. Consequently, low humidities among mesophytes often reflect critical conditions for growth. Except for minor variations, average day humidities were nearly identical in the two habitats during both seasons, although much higher in 1935. Average day minimum humidity gradually decreased after July 3, 1935, until a minimum of 20 per cent in

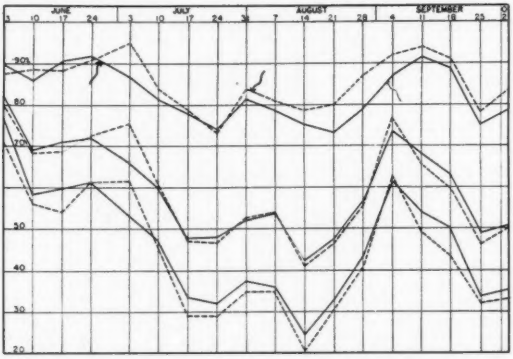


Fig. 9. Average day humidity by weeks in the alfalfa field (solid lines) and prairie (broken lines) during 1935. Upper graphs, maximum humidity; middle lines, average humidity; and lower graphs, minimum humidity. Dates of cutting alfalfa are indicated by heavy arrows; date of mowing prairie, by light arrow.

the prairie and 24 per cent in the alfalfa was reached during the second week of August (Fig. 9). From July 10 to August 28, during the period when humidity was consistently lower in the prairie, it averaged 33 per cent in the grassland and 36 in the field. The slightly higher humidity in the alfalfa was probably due to greater transpiration, for as Loftfield (1921) has shown, the stomata of alfalfa are open throughout the day. Alfalfa plants cannot roll and fold their leaves and thus reduce water loss as is commonly done by the prairie grasses. Average maximum day humidities were slightly higher during both years in the prairie (Table 7). These are attained early in the morning, usually between 4 and 6 a.m. At this time the leaves of the prairie grasses are unfolded and transpiration is not so closely guarded. Loftfield (1921) explains that the stomata of alfalfa are closed early in the morning, thus decreasing transpiration. There was a tendency during both seasons for the relative humidity to be slightly higher in the prairie until day temperatures approached 100° F.

TABLE 7

Seasonal average relative humidities (per cent).

	1935		1936	
Criteria	Prairie	Alfalfa	Prairie	Alfalfa
Average day maximum	85.5	82.7	67.1	63.9
Average day humidity	59.5	59.7	40.4	40.2
Average day minimum	44.0	46.3	26.5	26.9
Average night maximum	87.8	82.3	67.9	65.4
Average night humidity	82.5	76.5	61.4	58.8
Average night minimum	75.7	69.5	53.7	51.6

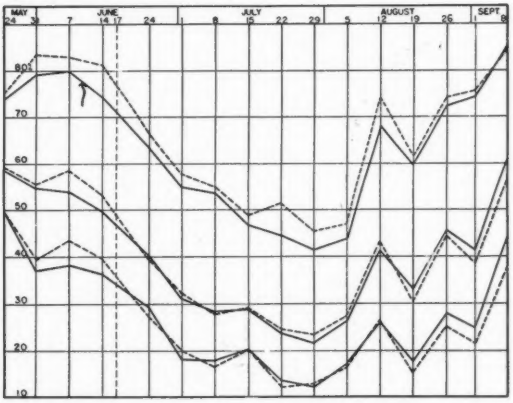


Fig. 10. Average day humidity by weeks in the alfalfa field (solid lines) and prairie (broken lines) during 1936. Upper graphs, maximum humidity; middle lines, average humidity; and lower graphs, minimum humidity. Date of cutting alfalfa is indicated by arrow.

During 1936, relative humidities were nearly 20 per cent lower, and there was even less variation between the two stations than during 1935 (Fig. 10). The average day minima gradually decreased after June 7, reaching a low of 12.1 per cent in the prairie during the week ending July 22, and 12.5 per cent in the alfalfa the following week. From July 1 to August 5 each station had an average day minimum of 16 per cent. From July 22 to August 5, minima were frequently only 5 and 6 per cent.

The average night humidity was 61 and 59 per cent for the prairie and alfalfa, respectively; this was 21 and 17 per cent lower than in 1935. The humidities at night were consistently higher in the prairie. The prairie grasses tended to unroll their leaves during these cooler hours giving the air easier access to the stomata, while those of the alfalfa (according to Loftfield) were tightly closed, thus checking transpiration.

Vapor Pressure Deficit

The vapor pressure deficits for one week of each growing season, when temperatures were highest and relative humidities lowest, are given in Table 8. These were calculated from the hygrothermograph records, the readings in inches of mercury being converted into millimeters.

Table 8

Maximum vapor pressure deficits in prairie and field by days for the driest and hottest weeks of each season.

	Temperature, degrees F.		Relative humidity, per cent		Vapor pressure deficit (mm. of mercury)		Excess deficit in prairie
	Prairie	Field	Prairie	Field	Prairie	Field	Millimeters
			August 7 to 13 inclusive, 1935				
	110	108	24	29	50.2	43.8	6.4
	118	112	15	20	70.5	54.7	15.8
	108	107	23	29	48.0	43.2	4.8
	112	108	22	27	54.6	45.0	9.6
	114	110	17	22	61.4	51.3	10.1
	94	89	24	23	31.1	26.8	4.3
	105	98	16	19	47.9	37.0	10.9
Av.	108.7	104.6	20.1	24.1	51.9	43.1	8.8
			July 15 to 21 inclusive, 1936				
	111	111	11	12	60.5	58.5	2.0
	119	117	11	13	75.8	70.1	5.7
	123	121	7	8	87.9	56.2	31.7
	118	116	13	15	72.1	65.5	6.6
	117	115	13	15	70.1	64.2	5.9
	98	98	20	20	37.0	37.0	0.0
	106	104	10	12	52.9	47.8	5.1
Av.	113.1	111.7	12.1	13.6	65.2	57.0	8.1

A study of Table 8 shows that in every case, except two, during these days of extreme heat and drought the temperature ranged from 1° to 7° higher in the prairie than in the field. Likewise, the relative humidity in the prairie was always 1 to 6 per cent lower, with two exceptions. A small differ-

ence in vapor pressure deficit (2 mm.) occurred on July 15, 1936, when the temperature in both prairie and field was 111° and the difference in humidity was only 1 per cent. A difference of 15.8 mm. is shown on August 8, 1935, when the temperatures in field and prairie were 112° and 118°, respectively, and the humidities in the same sequence were 20 and 15 per cent. An extreme difference of 31.7 mm. in vapor pressure deficit occured on July 17, 1936, when the excessively high temperatures of 123° F. prevailed in prairie and 121° in the field. The humidities were only 7 and 8 per cent, respectively. Thus, during the times of greatest extremes, vapor pressure deficits were greater among the rolled and folded drought-resisting grasses than among the more deeply rooted, more mesic, cultivated legumes. Otherwise, they were in general very similar.

Wind

Midcontinental winds greatly increase transpiration from the plant and evaporation from the soil surface. The wind direction was usually southerly during the growing season. The air often became very hot and dry during July and August. Strong wind movement, known locally as "hot winds," accompanied by air temperatures of 110° F. or higher, is an occasional feature of this climate. It is one of the severest tests that vegetation has to endure. One or two days of hot winds often ruin a promising crop, withering the most exposed leaf tissue.

Wind movement was measured by means of anemometers of the standard Weather Bureau type operated at a height of 12 inches. Wind velocity near the soil surface varied inversely with the height and density of the cover of vegetation. During the greater part of June, 1935, it was slightly higher in the prairie, since the alfalfa exceeded the grasses in height by about 4 inches (Fig. 11). When the alfalfa was mowed, on June 26, average daily wind movement at that station increased more than two miles per hour. For the remainder of the season the averages were from .5 to nearly 3 miles greater in the field. As the crop increased in height after each cutting, wind movement gradually decreased as shown in Fig. 11. On August 1, just before the alfalfa was mowed a second time, the plants were 10 inches and the prairie

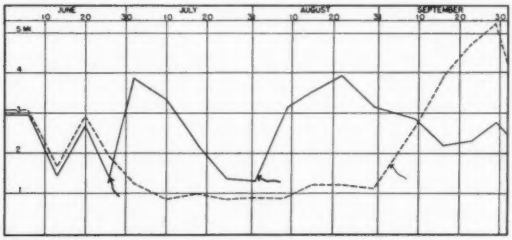


Fig. 11. Average wind movement in miles per hour by weeks in the alfalfa field (solid line) and prairie (broken line) during 1935. Dates of cutting alfalfa are indicated by heavy arrows; date of mowing prairie, by light arrow.

grasses 16 inches tall. After mowing, wind movement in the field increased steadily until the third week in August, at which time the plants had reached a height of 8 inches. It then gradually diminished, since the crop was not mowed thereafter. Wind increased following mowing of the prairie vegetation on September 3, and two days later it exceeded that in the field. For the remainder of the season the height of prairie vegetation was only about one-half that of the alfalfa.

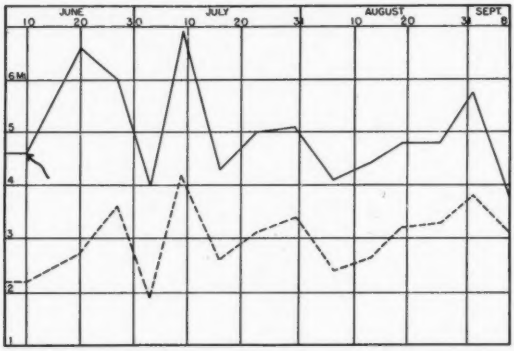


Fig. 12. Average wind movement in miles per hour by weeks in the alfalfa field (solid line) and prairie (broken line) during 1936. Date of cutting alfalfa is indicated by arrow.

Throughout 1936, wind movement in the field constantly exceeded that in the prairie by .7 to 3.9 miles per hour (Fig. 12). It was over twice as great at both stations as during the preceding summer, due to the dwarfed vegetation, although wind velocity at the Lincoln Weather Bureau was only .5 mile per hour higher from June to September, inclusive, than during 1935. The alfalfa exceeded the prairie vegetation in height by 5 inches until the field was mowed on June 10, yet wind averaged 2.4 miles per hour greater in the field. This was probably due to wind movement between the rows of the dwarfed plants as the rows were drilled north and south and the prevailing winds were southerly in direction. After June 10 the prairie grasses exceeded the alfalfa in height by 2 to 8 inches, since the latter made practically no growth during the remainder of the season. The plants in the two areas approached the same height after September 1, as the prairie grasses dried and decreased in stature while the alfalfa made a slight growth.

Prairie vegetation was much more effective in protecting the soil from air movement and consequent loss of moisture during the critical months of July and August. Readings were made with a hand anemometer at both stations during the latter part of July, 1935, when the alfalfa was 9 inches and the prairie grasses 16 inches tall. Wind velocities in the field at the soil surface and 3.5 inches above were .02 and 1 mile per hour, respectively. There was no wind in the prairie at these levels. In mid-August of the following year

measurements were made when the alfalfa and prairie grasses were 10 and 14 inches in height, respectively. Readings in miles per hour at the soil surface were .05 and .0 for the alfalfa and prairie; 10 inches above the soil they were 3.0 and 2.5; and just above the plants 4.1 and 3.5.

Light

A series of 44 measurements of light was made in each habitat with a Weston Sunlightmeter. These were taken at noon on clear days from June to August, 1935. Light intensities at the soil surface averaged 22 and 37 per cent of full sunshine in the prairie and field, respectively. Six inches above the soil they were 42 and 68 per cent in the same order. When the grasses were 12 inches tall and the alfalfa 17 during June, 1936, light intensities at the soil surface were 39 and 37 per cent, respectively, and 69 and 56 per cent six inches above the surface. Thus, during a season permitting rather normal growth, the light intensity was considerably higher in the field of young alfalfa, especially at the soil surface, than in prairie. This was due to a more uniform foliage cover in the grassland, caused by layering of the numerous species of plants which utilized light at all levels. This denser cover not only decreased the light intensity and wind movement, but also the evaporation, and in these respects resulted in a more uniform environment.

Evaporation

The rate of evaporation integrates in a general way the factors of humidity, wind movement, and temperature. Livingston's standardized, white, spherical, porous cup atmometers, fitted with non-absorbing devices were used. They were operated in pairs at each station at a height of 4 inches. All readings were reduced to those of the standard atmometers. The data for the two years are shown graphically in Figs. 13 and 14.

The evaporation was always much greater in the alfalfa field throughout both seasons, except during moist weather in June, 1935, when it was nearly the same at both stations. It was also less in the field after the prairie was mowed in September, 1935. The height of the plants greatly affected evaporation by modifying wind movement. Thus, marked increases were found fol-

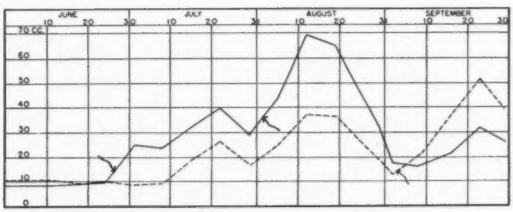


Fig. 13. Average daily evaporation by weeks in the alfalfa field (solid line) and prairie (broken line) during 1935. Dates of cutting alfalfa are indicated by heavy arrows; date of mowing prairie, by light arrow.

lowing mowing late in June and early in August. After the first cutting until September 3, the rate ranged from 5 to over 30 cc. per day higher than in the prairie where the grasses were 4 to 10 inches taller than the alfalfa. Maximum evaporation for the year was attained August 5 to 12, with an average daily rate of 69 cc. in the field and 37 cc. in the prairie. After the prairie was mowed on September 3, evaporation exceeded that in the field by 5 to 20 cc. daily. The average daily losses for the entire season in prairie and alfalfa were 23 and 29 cc. per day, respectively, or 26 per cent greater in the field.

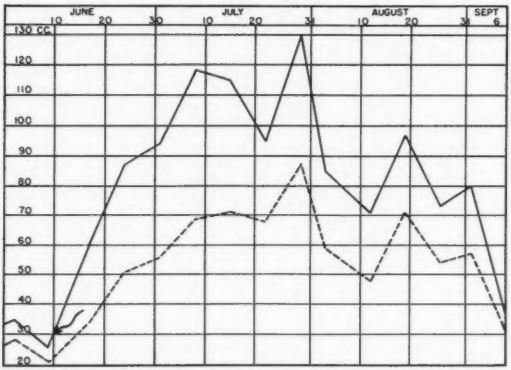


Fig. 14. Average daily evaporation by weeks in the alfalfa field (solid line) and prairie (broken line) during 1936. Date of cutting alfalfa is indicated by arrow.

During 1936, evaporation was over twice as great in prairie and nearly three times as great in the field as during the preceding season. Daily evaporation in the field constantly exceeded that in the prairie by 3 to 50 cc. (Fig. 14). Although the alfalfa was 4 to 6 inches higher than the grasses until June 10, yet water losses were 3 to 8 cc. per day greater. After mowing the alfalfa on June 10, evaporation greatly increased. As a result of the drought, the prairie vegetation thereafter exceeded the height of the leguminous crop by 2 to 8 inches. As drought became more severe, evaporation gradually increased until a daily maximum of 87 cc. was attained in prairie and 130 cc. in the alfalfa. This was during the last week of July. Increases in the maximum daily losses over those of 1935 were 135 per cent in the prairie and 88 per cent in the field. During the hottest part of the summer (July 1 to 29) the average daily loss was 74 cc. in the grassland and 114 cc. in the alfalfa. Average daily evaporation for the entire season was 52 cc. in prairie but 48 per cent greater (77 cc.) in the field.

Atmometers were also operated 20 inches above the soil surface at each station (July 17 to September 25, 1935) to determine the effect of an increase in height on evaporation. The average daily losses were 44 and 51 cc.

in the prairie and alfalfa, respectively, which were 15.5 and 15 cc. greater than from atmometers placed 4 inches above the soil. Hence, the increases were 54 and 42 per cent. Previous to September 3 evaporation from the more exposed atmometers in the field exceeded that from those in the prairie by 8 to 43 cc. per day, since scattered bunches of big bluestem and certain forbs about two feet high partially obstructed wind movement. After the prairie was mowed on September 3, rate of evaporation was reversed. Losses from the prairie atmometers exceeded those in the field by 5 to 10 cc. daily. Thus, the vegetation had a pronounced effect upon evaporation to a height of at least 20 inches above the soil.

Soil Temperature

Soil temperature is very important since it affects the biological, chemical, and physical processes of the soil. The rate of absorption of water and solutes by vegetation, the rate of growth of all underground plant parts, as well as the activities of soil microorganisms are all profoundly affected by soil temperature. The temperature of the soil indicates the efficiency of the vegetation as an insulator against solar radiation. It combines the effects of direct insolation, radiation, and cooling by the evaporation of moisture.

Soil temperatures were obtained by means of Friez' soil thermographs. The tubes were placed 3 inches below the soil surface in each habitat, without disturbance to the immediate plant cover, since they were fitted closely into holes made horizontally with a geotome. Throughout both seasons soil temperatures were consistently higher in the alfalfa field. Average daily maximum temperatures were 7.6° F. higher in the field during 1935, and 4.4° higher the following year (Table 9). Average day variations between maximum and minimum temperatures were 5.9° greater in the alfalfa during the first season and 2.1° the second, showing that the prairie has a more uniform environment.

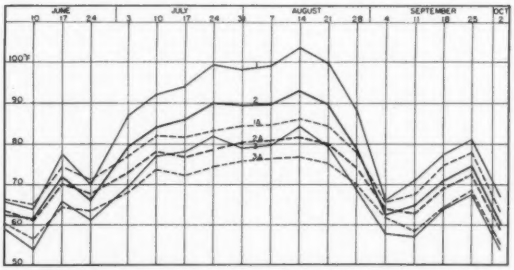


Fig. 15. Average day soil temperatures by weeks in the alfalfa field (solid lines) and prairie (broken lines) during the growing season of 1935. Upper graphs (1, 1a) maximum temperatures; middle lines (2, 2a) average temperatures; and lower graphs (3, 3a) minimum temperatures.

TABLE 9

Seasonal average of soil temperatures (degrees F.) and increase in temperature in field over that in prairie.

Criteria	1935			1936		
	Prairie	Alfalfa	Diff.	Prairie	Alfalfa	Diff.
Average day maximum	75.9	83.5	7.6	85.4	89.8	4.4
Average day temperature	71.9	76.5	4.6	79.7	83.0	3.3
Average day minimum	67.2	68.9	1.7	73.8	76.1	2.3
Average night maximum	72.5	77.3	4.8	81.5	85.6	4.1
Average night temperature	70.4	73.5	3.1	78.4	81.8	3.4
Average night minimum	68.4	70.4	2.0	75.8	78.5	2.7

During 1935, soil temperatures were practically the same at the two stations for the first three weeks of June when the alfalfa was two to four inches taller than the grassland vegetation (Fig. 15). When the alfalfa was mowed (June 26), soil temperatures immediately increased, reaching a seasonal high on August 14 with an average daily maximum of 103.9° F. The corresponding temperature in the prairie was only 86° F. At this time the prairie grasses were 14 inches tall but the alfalfa only 9 inches. During the five warmest weeks, average daily maximum soil temperatures were 99.9° and 84.5° in the same sequence. They rapidly decreased thereafter and differences between the two stations were less pronounced. Even after the prairie was mowed on September 3, although the alfalfa was 7 to 9 inches tall, maximum soil temperatures were still .5° to 3° higher in the field.

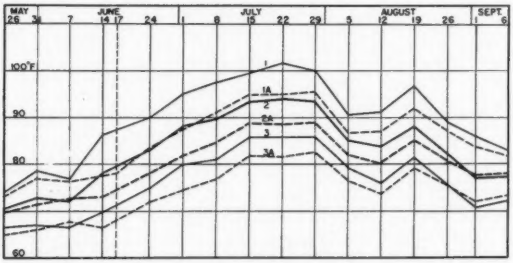


Fig. 16. Average day soil temperatures at 3 inches depth by weeks in the alfalfa field (solid lines) and prairie (broken lines) during the growing season of 1936. Upper graphs (1, 1a) maximum temperatures; middle lines (2, 2a) average temperatures; and lower graphs (3, 3a) minimum temperatures.

Throughout the season of 1936, differences between the two habitats were not so pronounced (Fig. 16). Temperatures in the field, however, were always consistently higher. The alfalfa exceeded the grasses in height 5 to 8 inches until June 10, but soil temperatures in the two habitats were nearly the same. Temperatures in the field increased sharply when the alfalfa was mowed on June 10, reaching a maximum of 101.5° F. during the middle of July, but only 95° in the prairie. During the five warmest weeks they were

99° and 93° F. in the alfalfa and prairie, respectively. After the first week in August, the vegetation in the two habitats more nearly approached the same height, since the grasses were drying while the alfalfa made a slight growth. Temperature of the field soil was 2° to 4° higher.

Although the average daily air temperatures were nearly 8° higher in 1936, yet the maximum daily soil temperature in the field for the 5 hottest weeks of the second season was approximately the same as in 1935. The alfalfa plants, during their second summer, were more effective in shading the soil. The maximum soil temperature in the prairie was 9° higher the second season due to the decreased growth of vegetation. Average night temperatures were over 3° higher in the field during both years (Table 9).

At a depth of one inch temperatures averaged 106° and 92° F. in the alfalfa and prairie, respectively, with maximum readings of 121° and 97° during the hottest part of 1935. They were 89° in the field and 80° F. in the grassland at a depth of six inches with maxima of 94° and 82°. The highest temperatures measured the following season, at 1 inch depth, were 112° and 104° F. in the alfalfa and prairie, respectively, and at six inches 102° and 91° F.

Readings were taken at 3 feet depth in each habitat in 1936 to ascertain to what depth differences in soil temperatures occurred at the two stations. They were 73° and 75° F., respectively, for the prairie and field at a time when the temperature of the surface soil in the prairie was 128° and the field 129°.

Discussion

The normally dense and uniform covering of prairie vegetation insulates the soil from the rays of the sun and results in less absorption of heat. Prairie sod is nature's stable condition, and represents the utmost in soil protection that the environment can continually support. In cultivated fields, protection of soil is greatly decreased, as shown by comparing soil temperatures in the alfalfa field and prairie during the middle of August, the hottest period of 1935. The difference between average day extremes was 19.5° in the field and 9.2° F. in the grassland. The minimum temperatures at this time were 84° and 76° F. in the same sequence. Temperatures at a depth of three inches were found to be over 8° lower in prairie than in an adjacent field of maize (Flory, 1936).

Bouyoucos (1916), working with grassland and bare soil in Michigan, reports that the maximum difference in soil temperature was reached in June and July when the grass sod, at seven inches depth, was about 6° F. cooler than bare soil. By September the difference disappeared, and in October the bare plots were colder and the sod warmer. The latter continued to have a high temperature through the fall and winter months. In extremely cold weather, soil with a cover of vegetation and a layer of snow had a temperature 25° F. higher at a depth of 3 inches than that of bare soil.

Too high temperatures in the surface soil greatly increase the vaporization

of water, tend to wither surface roots, and have a depressing influence on the activities of soil microorganisms, if indeed they do not destroy them. For example, it has been shown that nitrate production in eastern Nebraska proceeded at a maximum rate in moist prairie soil at about 94° F., but was reduced to less than one-fourth this rate at 110° F. (Russel *et al.*, 1925). The rate decreases very rapidly at higher temperatures until at 131° it may entirely cease.

The average air temperatures for the two seasons were nearly identical at the two stations. The mean maximum temperatures in grassland, however, were 2° to 5° F. higher. Moreover, the daily maxima were frequently higher, especially during the periods of greatest stress. A corresponding slightly higher humidity frequently occurred in the field among the vigorously transpiring plants which, it will be shown, were absorbing and transpiring much more water than prairie vegetation.

The marked effect of prairie vegetation, with its cover of variable height, in retarding wind movement is well known. There was always less air movement in the prairie, often very much less, although the alfalfa plants were taller. This profoundly affected the rate of evaporation, which was continuously much higher in the field, increasing it to nearly twice that of prairie during periods of greatest stress. All of these factors, both during the rather normal season of 1935 and the extremely dry one of 1936, have been integrated in water usage and plant growth in phytometers.

Phytometers

Phytometers devised by Dr. J. E. Weaver were used to measure water losses through transpiration and surface soil evaporation. The prairie phytometers were cylindrical, one-half square foot in cross-sectional area, and 30 inches deep. They were made of number 22 gauge galvanized iron and filled with surface prairie soil, which was tamped firmly, to a depth of 20 inches. A core of little-bluestem sod 8 inches deep and just large enough to fit tightly into the phytometer was taken from the prairie and pressed firmly into place. It filled the container to within 2 inches of the top. Six such phytometers were placed in holes 28 inches deep and three-fourths inch larger in diameter than the phytometers. Each hole was lined with a galvanized iron cylinder which extended about 2 inches above the soil surface to prevent any water from running in. The holes were in a straight row and spaced 8 inches apart. The soil surface in the phytometers was thus on the same level as the surface of the prairie.

Cylindrical containers, 8 inches high, 4.5 inches in diameter, and with sloping metal roofs open in the center, were placed in holes sunk to the proper depth in the center of the bottoms of the larger holes. A drainage tube, one-half inch in diameter, soldered to the center of the bottom of each phytometer can allowed excess water to empty directly into these sunken overflow cans (Fig. 17). A circular metal ring, approximately 3 inches in diameter and soldered about this tube, diverted any water running down the

outside of the phytometer into the hole about the smaller can. An auger hole in the bottom of this opening conducted such water into the subsoil. These phytometers, with tops set level, could absorb 3 to 5 inches of rain in a single storm without overflow, nor was any water lost from the soil or drainage can. There was no runoff nor run-in water to confuse the calculations.

These phytometers were weighed at two-week intervals during the season by means of a portable balance sensitive to one ounce (Fig. 18). Prairie phytometers each weighed about 125 pounds. A framework to hold a portable platform was arranged along two sides of the row of phytometers. Pairs of oak stakes 2 x 2 inches thick were driven into the ground, 3 pairs on each side of the row, and each pair was connected by means of a threaded iron rod, the stakes being held at a uniform distance by means of washers and nuts placed on each side of each stake. The height of the rods was 16 inches, which was just high enough to clear the fully grown grasses or to bend the tallest plants slightly without injuring them. The 2-inch planed planks, two

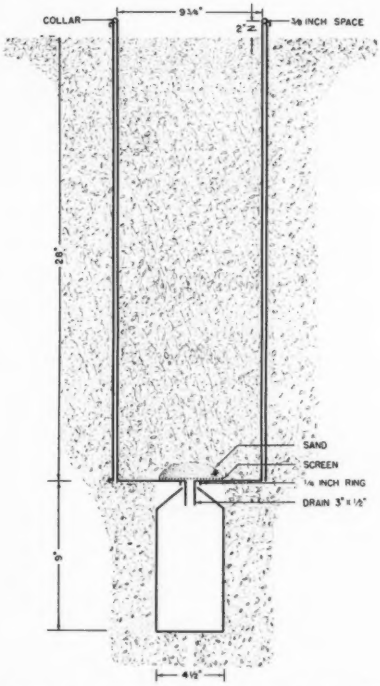


Fig. 17. Vertical section of phytometer used in prairie to determine loss of water by transpiration and surface evaporation.

on one side and one on the other, constituted the platforms which were supported by the rods only during weighing. When not in use, the planks were removed, the oak stakes scarcely modifying the habitat (Fig. 1). The phytometers, stakes, etc., were installed during very early spring before the renewal of growth of vegetation, great care being taken not to trample or otherwise disturb the site, which was temporarily protected by planks.

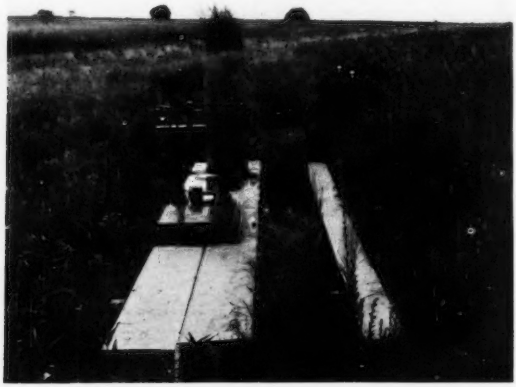


Fig. 18. The prairie station on August 2, 1935. Some phytometers have been partly withdrawn from the soil and another is on the weighing platform. Planks and scale in position for weighing.

Alfalfa phytometers were 9 inches square and 32 inches deep. They were filled with surface soil to within 6 inches of the top. Blocks of soil 9 inches square and 4 inches deep were taken from the alfalfa field in the early spring of 1935. These contained the young plants spaced in drill rows 4 inches apart. The blocks were firmly pressed into the phytometers. This left a 2-inch space to catch rainfall and to permit watering. An excellent growth resulted. The alfalfa phytometers each weighed about 160 pounds.

Ten alfalfa phytometers were placed in a trench in the field. The trench was 10 feet long and 20 inches wide, with two right-angled projections of similar width (Fig. 19). The whole trench was walled and floored with two-inch planks. It was covered with a hinged roof except the part holding the phytometers. The alfalfa phytometers, placed in one end of the trench, were surrounded on all sides but one by the field of alfalfa. Two containers of alfalfa were used as buffers for the remaining group of eight. Thus, as in the prairie, the experimental crop was entirely surrounded by an undisturbed crop of its kind (Fig. 19).

In weighing, the roof was opened at right angles, revealing the small plat-

form balance in the corner of the main trench. The phytometers were weighed in order, temporarily placed in the vacant right-angled projection of the main trench until all weights were recorded and then returned to their original position. Thus, there was no trampling or other disturbance of the surrounding crop.

Both lots of phytometers were first weighed each year about the middle of March, and after active growth began they were weighed at two-week intervals. Losses from the six prairie phytometers were very similar and all were used in calculating the pounds of water loss per square foot of soil. The two alfalfa phytometers bordering the trench in Fig. 19 showed considerable variation in water loss from the other eight and were not used in calculating results.

TABLE 10

Pounds of water added to each phytometer.

Station	April	May	June	July	August	September	October	November	Total
				Season of 1935					
Alfalfa	2		8	34	20	11	4	12	91
Prairie				16	14				30
				Season of 1936					
Alfalfa	4	20	31	56	43				154
Prairie			14	28	14				56

Fig. 19. Trench in alfalfa field showing the 10 phytometers in their normal position, the two in the foreground are buffers. The doors are closed on the short trench in which the phytometers were placed temporarily until all were weighed (Compare with Fig. 2). This arrangement afforded natural field conditions for the experimental plants. Photo. July 5, 1935.

Water Loss and Production of Dry Matter

The water losses are not the same as those of the natural prairie and alfalfa field, since water was added following weighings, when necessary, to restore the original weights. It is of interest that the prairie phytometers could be replenished in a single day, but in the field phytometers water was absorbed more slowly and the losses were restored only after a period of several days. These additions of water were made to keep the plants in good growing condition and to compensate the limited depth of soil in the phytometers. The amounts of water added are shown in Table 10.

Andropogon scoparius in the phytometers attained a height of 14 inches in 1935, which was nearly the same as that of the surrounding prairie. The height during the following season was 12 inches, despite the severe drought. It was the same as that outside until July 1. During the remainder of the season, the grasses in the phytometers remained green and continued growth, while those in the prairie wilted and dried. *Andropogon scoparius, A. furcatus, Sporobolus heterolepis, Bouteloua curtipendula,* and *Panicum scribnerianum* in the phytometers produced flower stalks during 1936. The plants in the alfalfa containers reached a maximum height of 16 inches during the first season and about 24 the second. They grew slightly taller both years than those in the field; otherwise growth was practically the same. The water losses followed the seasonal trends of temperature during both years and were, in general, inversely proportional to the humidity.

Water losses averaged 1.35 pounds per square foot of soil per day in the alfalfa and .89 pound in the prairie, from March 21 to September 17, 1935. In the field, average daily losses varied from .35 pound over periods of low water usage to 2.75 pounds when it was very hot and dry. Similar losses in grassland were .18 and 1.93 pounds (Fig. 20). During April and May about 0.2 and 0.4 pound of water were used or evaporated daily, the amount being greater in the field. Thereafter water usage gradually increased, reaching a maximum during July 22 to August 6, and then rather rapidly decreased. Alfalfa in the phytometers was cut on June 26, August 2, and

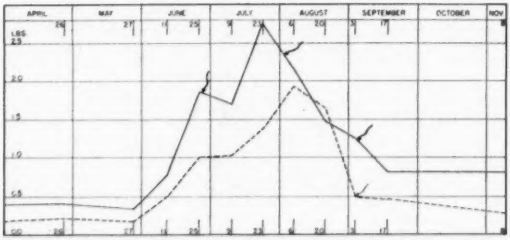


Fig. 20. Average daily water loss per square foot of soil as measured by phytometers in the alfalfa field (solid line) and prairie (broken line) during the growing season of 1935. Dates of cutting alfalfa are indicated by heavy arrows; date of mowing prairie, by light arrow.

September 3, when the plants were 16, 15, and 11 inches in height, respectively. After each cutting water losses decreased but only temporarily (if air temperatures increased) since rapid growth usually occurred. *Andropogon scoparius* in the prairie phytometers reached a maximum height of 16 inches the latter part of July. Its greatest water loss occurred during the two weeks ending August 6. The drying of the vegetation after height growth ceased caused a rapid decrease in transpiration (Fig. 20). It was greatest at each station during very hot periods when the plants had enough leaf surface to promote rapid transpiration. The grasses in the prairie phytometers were cut September 3 when they were 15 inches tall. During this season alfalfa required 1,283 grams of water to produce one gram of dry matter and the prairie approximately the same, 1,296 grams. Alfalfa produced 70 grams of dry matter per square foot of soil which was 58 per cent more than that of the prairie (44.3 grams).

Water losses during 1936 (March 13 to September 7) were 2.17 pounds per square foot of soil per day in the alfalfa field and 1.15 pounds in the prairie, an increase of 61 and 29 per cent, respectively, over 1935. Daily variations in the same sequence were from .33 to 3.59 pounds and .28 to 1.97 pounds (Fig. 21). Losses were much higher during this season of extreme heat and drought. They gradually increased at each station after April 19, reached a maximum during the intense heat of midsummer, after which they gradually decreased (Fig. 22). Alfalfa in the phytometers was cut on June 10 when it was 23 inches tall. Maximum losses occurred during the two weeks following July 20 when the plants were 5 inches tall. Although the plants remained green, they made no growth from June 29 to August 2, due

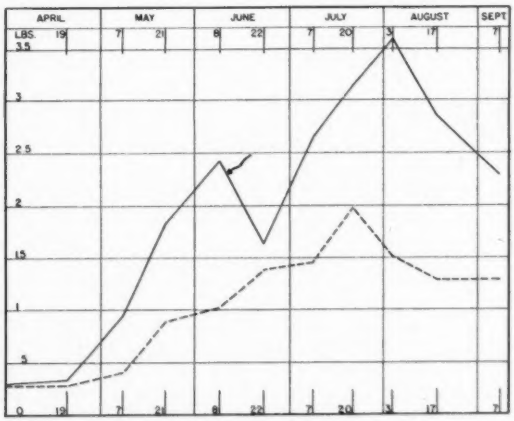


Fig. 21. Average daily water loss per square foot of soil as measured by phytometers in the alfalfa field (solid line) and prairie (broken line) during the growing season of 1936. Date of cutting alfalfa is indicated by arrow.

to excessively high temperatures. A height of 12 inches was attained, however, by the time of the final cutting on September 7.

Maximum losses in the prairie occurred during the two-week period ending July 20, when the grasses were 9 inches tall. The vegetation in the phytometers averaged 12 inches high at the time of cutting on September 7. The plants had grown only 2 inches since June 29. Scattered showers during August, and slightly lower temperatures and higher humidity decreased water losses.

During 1936 alfalfa required 2,498 grams of water to produce one gram of dry matter and prairie vegetation 2,684 grams. This is an increase for the alfalfa of 95 per cent over 1935, and 107 per cent for the prairie. The production of dry matter in grams per square foot of soil was 62 and 31 for the alfalfa and prairie, respectively. Thus, the alfalfa phytometers produced 100 per cent more dry matter than did those in the prairie.

An area one rod square was harvested at each station whenever the field was mowed in order to obtain the relative yields. During 1935 the two cuttings of alfalfa yielded nearly 2 tons per acre, and those in the prairie about 330 pounds less (Table 11). During the following year of drought, alfalfa yielded slightly less than 1 ton per acre while the yield of the prairie was approximately three-fourths as great. Alfalfa made practically no second growth and the prairie but little, hence neither was again harvested. It is of interest that the prairie hay consisted of approximately 80 per cent grasses and 20 per cent forbs; the latter were mostly *Erigeron ramosus* and *Amorpha canescens*.

Fig. 22. The prairie station looking east on August 5, 1936. The station in the field is in the background. The dried prairie grasses are only 5 to 6 inches tall. Screen cages were temporarily placed over both lots of phytometers to protect the green and growing plants from grasshoppers.

TABLE 11
Yield in pounds of dry matter per acre in field and prairie.

Date	Alfalfa	Prairie
June 26, 1935	2,440	2,720
August 2, 1935	1,400	790
Total	3,840	3,510
June 10, 1936	1,920	1,459

DISCUSSION

Alfalfa used nearly ¾ pound or 72.5 per cent more water daily per square foot of soil than the plants of the prairie. During the first season the two crops were approximately equal in grams of water used to produce a gram of dry matter, but the alfalfa was slightly more efficient during the year of extreme drought. This was due not to the smaller amount of water used but to the greater amount of dry matter produced by alfalfa. During 1936, this crop used 89 per cent more water per square foot of soil per day than prairie but produced 100 per cent more dry matter. Stated conversely, the prairie species responded to the extreme conditions of drought by decreased growth and consequently less expenditure of water.

Weaver and Crist (1924) obtained an average daily loss of .85 pound of water per square foot of soil from upland prairie during a cloudy, humid period of 15 days in midsummer. In an alfalfa field losses were 1.1 pounds during the same period. An upland prairie near Lincoln used 1.46 pounds of water daily during the growing seasons of 1931 to 1933 inclusive (Flory, 1936). During the two years of this investigation the prairie required an average of 1.02 pounds and the alfalfa 1.76 pounds of water per square foot of soil. Prairie vegetation required 1,296 grams of water to produce one gram of dry matter during the rather favorable season for growth, 1935. Two years previously under similar conditions Flory (1936) ascertained that 1,376 grams were used.

Briggs and Shantz (1913) showed that there was an increase in the water requirement when the moisture content of the soil was either too high or too low. It was higher in an infertile soil whether sand or clay than in a fertile one. Thus, the use of fertilizers reduces the water requirement. An insufficient soil mass increases it, probably as a result of an insufficient supply of nutrients. Differences in water requirement occur in different varieties of the same crop. It is higher in dry than in moist air. Shading increases the water requirement by decreasing the rate of food manufacture.

During a 10-day period of maximum transpiration, Briggs and Shantz (1916) found that alfalfa lost almost one-half of the total water transpired in the production of the second crop. They state that alfalfa increases steadily in transpiration rate to a maximum at or near the time of cutting. They found that the crop doubled its transpiration rate every eight days throughout practically the whole period between cuttings. The same investigators (1917) showed that the rate of evaporation has a marked effect upon transpiration. It required 518 tons of water to produce one ton of alfalfa at Williston, North Dakota; 853 tons at Akron, Colorado; but 1,085 tons at Dalhart, Texas. Dillman (1931) states that the early summer crop of alfalfa was

nearly always produced with a lower water requirement than the midsummer crop, and the latter more economically than the late summer crop.

The prairie grasses evidently are not as efficient in the use of water as alfalfa. Free (1936) explains the condition of less runoff and less soil moisture under bluegrass sod as compared with corn as due to greater losses by evaporation and transpiration from the former crop. Conversely, Shantz and Piemeisel (1927) found that buffalo and grama grass had a very low water requirement.

Although alfalfa may produce higher yields and is a soil builder and a valuable forage crop, yet its value compared to native prairie, when all factors are considered, may be questioned. Alfalfa depletes subsoil moisture, thus creating a serious problem in dry areas or in dry weather cycles. Normally there is available moisture at all depths in prairie, since the deeper supply is drawn upon only by certain legumes, composites, and other scattered, deeply rooted forbs. Very much more runoff may be expected from an alfalfa field, in addition to a considerable loss of soil by erosion. The average daily water loss from a field, even of young alfalfa, may exceed that of nature's mean, as illustrated in the prairie, by 16 tons of water per acre per day.

Thus, in a climate where severe droughts occur periodically, depleting soil moisure, ruining crops, and initiating dust storms, serious consideration should be given to the many advantages of native vegetation over a long period of years. While it would not be advisable in good agricultural practice to leave the entire area in its natural state, large tracts should have been left to temper the environment, conserve moisture, and protect the soil from erosion by wind and water. As pointed out by Flory, there is great need of the reestablishment of types of cover similar to the climax vegetation. Nor should the requirements of such vegetation exceed those of the climax, as does alfalfa. Much further study of equilibria found in nature is needed, since they furnish the fundamental foundation upon which man must rely in administration of natural resources (cf. Smith, 1932; Weaver and Flory, 1934).

Summary

A comparison of the environment, growth, and water loss in upland prairie and an adjacent alfalfa field was made at Lincoln, Nebraska, during the growing seasons of 1935 and 1936. The year 1934 was one of such extreme drought that soil moisture reserves were almost exhausted. Precipitation during 1935 was 25 inches, or 3 inches below the mean (27.98 in.), but that of the following year was only 14 inches. Despite the light rainfall, runoff was nearly 11 times as much in the alfalfa field as in prairie.

Available soil moisture was greater in the prairie at all depths and especially in the deeper layers (3 to 7 feet) during both years. Alfalfa dried the soil more completely and to greater depths than did prairie vegetation. Alfalfa roots reached a depth of 12 feet when the plants were two years old; the native bluestem and other grasses absorb mostly in the first 3 to 6 feet, although many forbs extend deeper.

Survival in the field of alfalfa, planted in early fall of 1934, was only 37

per cent as great in midsummer, 1937, as in July, 1935. The stand appeared normal during each season.

Average day air temperatures by weeks in the two habitats ranged from 60° to 99° F. and were nearly identical in field and prairie during both seasons, although average maximum day temperatures were slightly higher in the prairie. Extreme average maximum temperatures of 112° to 114° F. occurred during 1936.

Average day soil temperatures by weeks at 3 inches depth varied from 59° to 94° F. and average maximum day temperatures from 63° to 104° F. Prairie vegetation was more effective than alfalfa in protecting the soil against temperature changes. Soil temperatures were consistently higher in the alfalfa field. The day temperature averaged 4° higher and the maximum day temperature 6°.

Average variations between maximum and minimum soil temperatures during the day (55° to 95° in the prairie) were 4° F. greater in the alfalfa field. Soil temperatures at a depth of an inch averaged 92° and 106° F. in the prairie and field, respectively, on certain hot afternoons during July and August, 1935, and 80° and 89° F. at 6 inches depth. Day air temperatures 4 inches above the soil in the prairie averaged nearly 8° F. higher than those of the soil at 3 inches depth, but they were only 3° higher in the field.

Average weekly maximum day humidities were 3 per cent higher in the prairie. Minimum day humidities ranged from 20 to 77 per cent in 1935, but were much lower (12 to 50 per cent) during 1936. Average weekly day humidities were nearly the same in the two habitats, ranging from 41 to 82 per cent during the rather normal summer of 1935. Average weekly night humidities were 4.3 per cent higher in the prairie, where the range during 1935 was 57 to 97 per cent. During 1936 it varied from 34 to 82 per cent.

Wind movement a foot above the soil surface averaged .4 mile per hour greater in the field during the first growing season and 2 miles the second Air movement of 3 to over 6 miles per hour was frequent.

Evaporation at a height of 4 inches above the soil was 15.5 cc. per day greater in the alfalfa field. Average daily losses by weeks ranged from 8 to 69 cc. in the field and prairie during 1935, and 21 to 130 cc. in 1936. Evaporation from atmometers 20 inches above the soil surface, and thus above the general level of the plants, was 54 per cent greater in the prairie and 42 per cent greater in the field than from atmometers operated at 4 inches in height.

Light intensities at the soil surface in prairie and alfalfa were 22 and 37 per cent, respectively, of full sunlight. Six inches above the soil they were 42 and 68 per cent in the same sequence.

A new type of phytometer containing native sod was devised for the study of water usage by grasses. These phytometers were 2.5 feet deep and had a surface area of one-half square foot. Allowing both transpiration and surface soil evaporation, and being surrounded entirely by undisturbed native vegetation, they permitted determinations of actual water usage. Field phytometers of slightly larger area were likewise completely surounded by field plants of alfalfa.

The average daily water loss per square foot of soil was .89 pound in prairie and 1.35 pounds in the field during 1935. It varied from .2 to 1.9 pounds, with varying transpiring surface and environmental conditions, in prairie and from .4 to 2.8 pounds in the field. The losses per unit area averaged 1.15 and 2.17 pounds in prairie and field in 1936, the range varying from .3 to 3.6 pounds, respectively.

Water usage per gram of dry matter produced was 1,296 and 1,283 grams in prairie and alfalfa, respectively, during 1935, but 2,684 and 2,498 grams during the summer of great drought. Based on yields from the phytometers, alfalfa produced 58 and 100 per cent more dry matter per square foot of soil during the two years than did prairie.

Yield per acre from the field of alfalfa during 1935 was 3,840 pounds, from prairie 3,510 pounds. Corresponding yields for the drought year were only 1,920 and 1,459 pounds.

The greater yields of alfalfa are at the expense of excess water (here furnished the phytometers) of both soil and subsoil, which are thoroughly dried. In the light of experimental evidence, the practice of growing alfalfa on uplands in regions of limited precipitation and thus for a time exceeding the normal possibilities of the environment in terms of crop production seems unwise. Losses in water content, soil structure, runoff, and erosion ensue, which do not occur under a cover of grassland, either natural or artificial.

The writer is deeply indebted to Dr. J. E. Weaver for outlining the problem and for valuable suggestions throughout the entire course of the work.

REFERENCES

ALWAY, F. J. 1913—Studies on the relation of the non-available water of the soil to the hygroscopic coefficient. Neb. Agric. Exp. Sta., Res. Bull **3**.

———, G. R. MCDOLE, AND R. S. TRUMBULL. 1919—Relation of minimum moisture content of subsoil of prairies to hygroscopic coefficient. Bot. Gaz. **67**:185-207.

BOUYOUCOS, G. J. 1916—Soil temperature. Mich. Agric. Exp. Sta., Tech. Bull. **26**.

BRIGGS, L. J. AND H. L. SHANTZ. 1913—The water requirement of plants. U. S. Dept. Agric., Bur. Plant Ind., Bull. **284**.

———1916—Daily transpiration during the normal growth period and its correlation with the weather. Jour. Agric. Res. **7**:155-212.

———1917—The water requirement of plants as influenced by environment. Second Pan-American Scientific Congress, Wash., D. C. Dec. 27, 1915—Jan. 8, 1916. Government Printing Office, Washington.

CLARK, O. R. 1937—Interception of rainfall by herbaceous vegetation. Science **86**:591-592.

DILLMAN, A. C. 1931—The water requirement of certain crop plants and weeds in the Northern Great Plains. Jour. Agric. Res. **42**:187-238.

DULEY, F. L. 1929—The effect of alfalfa on soil moisture. Jour. Amer. Soc. Agron. **21**:224-231.

FLORY, E. L. 1936—Comparison of the environment and some physiological responses of prairie vegetation and cultivated maize. Ecology **17**:67-103.

FORSLING, C. L. 1931—A study of the influence of herbaceous plant cover on surface run-off and soil erosion in relation to grazing on the Wasatch Plateau in Utah. U. S. Dept. Agric., Tech. Bull. **220**.

FREE, G. R. 1936—A comparison of soil moisture under continuous corn and bluegrass sod. Jour. Amer. Soc. Agron. **28**:359-363.

KIESSELBACH, T. A., A. ANDERSON, AND J. C. RUSSEL. 1934—Subsoil moisture and crop sequence in relation to alfalfa production. Jour. Amer. Soc. Agron. **26**:422-442.

———, J. C. RUSSEL, AND A. ANDERSON. 1929—The significance of subsoil moisture in alfalfa production. Jour. Amer. Soc. Agron. **21**:241-268.

LOFTFIELD, J. V. G. 1921—The behavior of stomata. Carnegie Inst. Wash., Pub. **314**.

LOWDERMILK, W. C. 1930—Influence of forest litter on runoff, percolation, and erosion. Jour. For. **28**:474-491.

MARVIN, C. F. 1915—Psychrometric tables for obtaining the vapor pressure, relative humidity, and temperature of the dewpoint. U. S. Dept. Agric., Weather Bureau Bull. **235**.

MILLER, M. F. AND H. H. KRUSEKOPF. 1932—The influence of systems of cropping and methods of culture on surface runoff and soil erosion. Mo. Agric. Exp. Sta., Res. Bull. **177**.

NOLL, W. C. 1938—Environment and physiological activities of winter wheat and prairie during a year of extreme drought. Unpublished Ms.

RUSSEL, J. C. 1929—Organic matter problems under dry-farming conditions. Jour. Amer. Soc. Agron. **21**:960-967.

RUSSEL, J. C., E. G. JONES, AND G. M. BAHRT. 1925—The temperature and moisture factors in nitrate production. Soil Science **19**:331-398.

SHANTZ, H. L. AND L. N. PIEMEISEL. 1927—The water requirement of plants at Akron, Colorado. Jour. Agric. Res. **34**:1093-1190.

SMITH, R. C. 1932—Upsetting the balance of nature, with special reference to Kansas and the Great Plains. Science **75**:649-654.

TYSDAL, H. M. 1934—Determination of hardiness in alfalfa varieties by their enzymatic responses. Jour. Agric. Res. **48**:219-240.

WEAVER, J. E. 1926—Root development of field crops. Pp. 215-218. McGraw-Hill Book Company, Inc., New York.

——— AND F. W. ALBERTSON. 1936—Effects of the great drought on the prairies of Iowa, Nebraska, and Kansas. Ecology **17**:567-639.

——— AND F. E. CLEMENTS. 1938—Plant ecology, second edition, p. 206. McGraw-Hill Book Company, Inc., New York.

——— AND J. W. CRIST. 1924—Direct measurement of water loss from vegetation without disturbing the normal structure of the soil. Ecology **5**:153-170.

——— AND T. J. FITZPATRICK. 1934—The prairie. Ecol. Monogr. **4**:109-295.

——— AND E. L. FLORY. 1934—Stability of climax prairie and some environmental changes resulting from breaking. Ecology **15**:333-347.

——— AND W. J. HIMMEL. 1931—The environment of the prairie. Univ. Neb. Conservation and Surv. Div., Bull. **5**.

———, V. H. HOUGEN, AND M. D. WELDON. 1935—Relation of root distribution to organic matter in prairie soil. Bot. Gaz. **96**:389-420.

——— AND W. C. NOLL. 1935—Comparison of runoff and erosion in prairie, pasture, and cultivated land. Univ. Neb. Conservation and Surv. Div., Bull. **11**.

———, L. A. STODDART, AND W. NOLL. 1935—Response of the prairie to the great drought of 1934. Ecology **16**:612-629.

UNIVERSITY OF NEBRASKA,
LINCOLN, NEBRASKA.

The Effect of the Moisture-Retaining Capacity of Soils on Forest Succession in Itasca Park, Minnesota

Lucille Lora Kell

I. Introduction

Itasca Park is so located that its vegetation has been and still is of much interest ecologically. The park, which covers approximately 13,000 hectares, is located rather uniquely in respect to three major plant formations. It lies in northern Minnesota in a transition area between the subarctic fir-spruce-birch region, which is well developed northeast of here, and an area of pure summer-green forest to the west. In this broad transition region, the park is closest the western edge. The summer-green forest to the west is a narrow belt extending in a northerly direction, beyond which lies the extensive central grassland province of North America.

The mean annual precipitation is low for a forested area: 60.1 cm. About 75% of this rain is received during the six warmest months. The amount and distribution of the precipitation closely resembles that characteristic of the prairie area west of Itasca Park, and consequently would seem none too favorable for forest growth. This prairie aspect of the climate exerts a strong influence on forest distribution, in that water-balance becomes a critical factor in determining the distribution of the major forest types. Theoretically, at least, any factor which might compensate for the xericism of the environment should be of critical ecologic significance in this zone of transition where two major forest formations are competing for possession of the area.

One of the most important factors affecting water-balance is soil texture, and the texture of the soil varies tremendously in this region. Itasca Park is well within the area of Pleistocene glaciation. The topography is interspersed with many lakes and marked by numerous morainic knolls and ridges. The last glacier which entered this region had passed over a limestone area. Patches of the drift which were not altered by glacio-fluvial action are consequently calcareous clays. Mixed and alternating with these are deposits of gravels, sands and loams. Both horizontally and vertically there are often sharp lines of demarkation between very fine and very coarse soils. This wide variability of soil texture causes a corresponding variability in water-holding capacity, and this character of the soil might be expected to have considerable significance in view of the critical nature of the water-balance.

After the last glacier receded from this region, bare areas were left: areas on which no life existed. As the glacier retreated northward, species of plants and animals migrated into the baren areas shortly after they were uncovered. The two general types of habitats in the region—lakes and glacial till—became populated with species tolerant of the conditions existing in their respective habitats. Thus there were two general courses of vegetational

development in the park: those beginning in lake habitats and ending in a permanent forest on peat, and those beginning on glacial drift and terminating in permanent forests on mineral soils.

There are two types of hydroseres in the region, each of which is rather distinct floristically. Eventually both lines converge and result in one climax on peat.

TABLE 1

Density of Trees per 100 Square Meters, Ash-Elm-Fir Climax.

Species	0-1 dm. D.B.H.		1-2 dm.	2-3 dm.	3-4 dm.	4-5 dm.
	Under 1 m. tall	Over 1 m. tall				
Fraxinus nigra Marsh.	306.8	7.5	1.6	1.2	0.7	0.2
Ulmus americana L.	13.1	0.2			0.2	
Abies balsamea (L.) Mill.	151.1	0.5	0.9			
Betula papyrifera Marsh.		0.2	1.1			
Populus tremuloides Michx.	6.9	0.2				
Populus balsamifera L.	3.1					
Quercus macrocarpa var. *olivaeformis* Michx. f.	0.6					
Picea mariana (Mill.) BSP.	3.1					

This climax on peat is characterized, principally, by three species of trees: *Fraxinus nigra, Ulmus americana,* and *Abies balsamea.* Plot studies indicate that this community is definitely climax (Table 1). Ash seeds germinate well, and, although there is a natural thinning of the seedlings, the species is well represented in the larger size classes. *Ulmus americana* is second in importance. Two size classes are missing in the data, but a check in the field proved this to be due to chance in the selection of sample plots. This species is well represented in all size classes up to 4 decimeters D.B.H. *Abies balsamea* is the third most important tree and seems to be holding its place as a minor member of the peatland climax. *Betula papyrifera* is occasionally seen in this permanent community but certainly is not an important species. No seedlings of it occurred in the sample plots and the tree does not attain as great size on peat as on the uplands.

Fraxinus pennsylvanica Marsh. and *Acer rubrum* L. were observed occasionally in this climax. *Acer spicatum* Lam. and *Alnus incana* (L.) Moench. are important shrubs in the plots studied.

There is no indication from plot studies, or from other field observations by the writer, that upland forest communities are invading the peat. Thus there can not be only one permanent community in this area as previous workers have indicated. The peat soils have one of the three types of forest climaxes occurring in this region.

On the glacial till we are unable to trace vegetational development from the first bare condition of the habitat because of the long interval since glacia-

tion. Seres on gravel pit areas are hardly reliable indicators of the conditions of the past for several reasons: (1) these represent only gravel areas, (2) the vegetation surrounding the pits modifies the environment considerably, and (3) the biota has changed continuously by immigration during the post-glacial interval.

In the present study, the writer has considered only the development that has followed the fires which were very frequent until 1907, but which have been absolutely eliminated within the park since then. Stages of secondary succession following fire can be easily traced in the field today. The pioneer forests on burned areas are composed of jack pine (*Pinus banksiana* Lamb.), red pine *(P. resinosa)*, white pine *(P. strobus)*, mixtures of these, or birch-aspen *(Betula papyrifera-Populus tremuloides)*. All of these species are intolerant of conditions imposed upon their communties by the invasion of more tolerant species. The pines are sometimes found giving way to an intermediate forest stage of birch-aspen or other pines, but are sometimes invaded directly by fir-spruce-birch or maple-basswood communities.

Previous ecological studies in this region are not in agreement with respect to the successional status of these forest associations. Certain investigators have concluded that pines in northern Minnesota are permanent, that is, climax communities. Bergman and Stallard (1916) traced a hydrosere from *Chara* through *Abies-Betula* to *Pinus strobus-P. resinosa* climax. Later, Stallard (1929) attempted to show that white pine terminates the secondary succession, also. The writer's field observations do not support this view for Itasca Park. Pines can not be found on even the oldest peat areas, and, rather than invading fir forests, they are obviously being invaded by the more tolerant species! Bergman and Stallard admittedly used Clements' concept as expressed in "Plant Succession" (Clements, 1916) as a basis for their work. Clements apparently still holds to his original views, for he indicates (Weaver and Clements, 1938) a climax of white pine-red pine-hemlock for northern Minnesota.

Nichols (1935) excludes red pine from his hemlock-white pine-hardwood climatic climax, and believes that mixed stands of the three pines represent a "physiographic" (edaphic?) climax on poorer soils. From observations in northern Michigan, he generalizes to the effect that white pine, throughout its range, is a normal, although minor, species of the climatic climax. Recently, Eggler (1938), though finding no white pine reproduction, states that it is a minor species of the sugar maple-basswood climax in Wisconsin.

Lee (1924) considers *Pinus banksiana* to be edaphic climax on the poorer sandy soils in Itasca Park. On sandy loams, he states, *Pinus resinosa* invades jack pine and persists as an edaphic climax. He places white pine *(P. strobus)* parallel with sugar maple *(Acer saccharum)* on heavy clay soils for the present—as a theoretical edaphic climax in the future. Lee admits that *Pinus strobus* fails to reproduce in its own shade and where the thick undergrowth prevents the establishment of its seedlings. How, then, can it be parallel with the extremely tolerant *Acer saccarum* either now or in the future?

Fig. 1. Supressed growth of *Abies balsamea* and *Picea glauca* under *Pinus resinosa*. Note the complete lack of reproduction of the pine. Photograph near Station 6.

Fig. 2. One of the large *Pinus strobus* which are scattered through the Acer-Tilia forest at Station 20. The measuring rod is marked off in decimeters. There are many pine seedlings in such stands, but none succeeds even under openings made by the death of a large tree.

A great number of other investigators, as reviewed by Grant (1934), consider the pines as temporary in the Lake States region.

The successional status of the upland forest types, as derived from field notes by the writer, is as follows.

In Itasca Park, relatively old stands of jack pine may be found in which there is no understory to indicate a succession to another forest type, nor is this pine reproducing in its own shade. Other stands of this pine are obviously being replaced by red pine, red pine-white pine mixtures, or fir-spruce-birch forests.

Old stands of red pine, which appear to have been pioneer forests on burned areas, usually show evidence that they are being replaced by fir-spruce-birch (Fig. 1) or less commonly by sugar maple-basswood.

All old stands of white pine are being replaced by sugar maple-basswood (Fig. 2).

It is very evident that these two climaxes (fir-spruce-birch and sugar maple-basswood) which usually follow the pines are not at all mixed. Often they occur side by side with a surprisingly narrow transition between. Grant (1934), working 129 kilometers east of Itasca Park, concludes that in that region there is one upland climax in which fir and basswood are dominants. In reviewing Lee's work, Grant infers that in Itasca Park the climax is, likewise, a smiilar mixture of the two. The writer's field observations do not justify this supposition.

Plot studies in the sugar maple-basswood and fir-spruce-birch types substantiate the writer's view that these are both climax types in Itasca Park.

TABLE 2

Density of Trees on Size Classes per 100 m², Fir-Spruce-Birch Community

Species	0-1 dm.	D.B.H.	1-2 dm.	2-3 dm.	3-4 dm.
	Under 1 m. tall	Over 1 m. tall			
Abies balsamea (L.) Mill.	186.0	20.0	4.5	0.2	
Picea glauca (Moench) Voss.	1.0	1.4	1.9	0.4	
Betula papyrifera Marsh.	0.4	0.4	0.6	0.2	
Populus tremuloides Michx.	2.9		1.1	2.2	
Pinus resinosa Ait.			0.2		0.4
Pinus strobus L.	0.4				
Fraxinus spp.	5.4				
Acer rubrum L.	0.2				
Ulmus americana L.	2.0				

In the fir-spruce-birch community (Table 2), *Abies balsamea* seeds prolifically and although thinning is severe, reproduction is slightly more successful than with any other species. Seeds of *Picea glauca* rarely germinate, but of those that do, very few fail to live to maturity. *Betula papyrifera* is an intolerant species; however, it is able to complete its life cycle by starting in better-lighted areas under openings in the canopy. These data concerning

the dominant species are in essential agreement with Cooper's (1913) observations on Isle Royale where this community is the climatic climax.

Pinus strobus, Fraxinus spp., *Acer rubrum,* and *Ulmus americana* are all able to germinate but can not persist in this community. *Populus tremuloides* is an intermediate successional species, starting before the canopy becomes dense, but is unable to hold its own as the climax approaches maturity. A few root suckers are found (making up the "seedling" size class of this species in Table 2) which die out before reaching a meter in height.

The few representatives of *Pinus resinosa* present are all old trees and indicate the nature of the apparent pioneer stage.

The sugar maple basswood community is another, but more complex, type of climax on mineral soils (Table 3). Like *Abies* in the fir-spruce-birch, *Acer saccharum* seeds germinate well. Thinning is severe but still *Acer* has a good representation in the higher size classes. *Tilia americana* does not reproduce by seeds very often. Suckers are produced around stumps and uninjured trees as well. Evidently, once a seedling survives, the tree is perpetuated indefinitely on the spot by sprouts—a condition apparently characteristic of the sugar maple-basswood type farther south in Minnesota (Daubenmire, 1936).

TABLE 3

Density of Trees by Size Classes per 100 m.2, Sugar Maple-Basswood Climax.

Apparent status	Species	Size classes in dm. D.B.H.				
		0–1	1–2	2–3	3–4	4+
Permanent	*Acer saccharum* Marsh.	2.20	.86	.35	.06	
	Tilia americana L.	1.75	.81	.07	.11	.03
	Ostrya virginiana (Mill.) K.Koch.	4.60	.20	.03	*	
	Ulmus americana L.	.47	.16	.55		
	Quercus borealis Michx. f.	.14	.07	.03	.03	
	Fraxinus nigra Marsh.	1.00	.10	.03		
	Quercus macrocarpa var. *olivaeformis* (Michx. f.) Gray	.17	.07			
Disappearing relics of seral forest	*Populus tremuloides* Michx.	.39†	.94	.55	.43	
	Betula papyrifera Marsh.	.53†	.50	.07	.03	
	Pinus strobus L.	2.60			.03	0.3
	Populus balsamifera L.			.07		
	Betula lutea Michx. f.		.04			
Capable of germination but not of maturation	*Picea glauca* (Moench) Voss.	.03				
	Populus grandidentata Michx.	.02				
	Ulmus fulva Michx.	.30				

* Species does not attain this size in our region.
† Suckers, no seedlings.

Ostrya virginiana, a small tree, is a characteristic minor species of this climax. Likewise, the oaks, American elm, and ash are permanent although minor species accompanying sugar maple and basswood.

Populus tremuloides and *Betula papyrifera* are members of a seral forest as indicated by many large dead trees and the lack of seedlings. A few of

the root suckers (recorded as 0-1 dm. D.B.H.) of these species may be able to develop to maturity, but their vegetative reproduction is far less successful than that of *Tilia*.

Pinus strobus is represented by a scattering of large trees.

These data indicated that *Pinus strobus*, as a possible pioneer, is followed by an intermediate stage of *Populus tremuloides* and *Betula papyrifera* and then by the *Acer-Tilia* permanent community.

II. Statement of Problem

The problem as presented for investigation consists of an attempt to determine the extent to which the moisture-holding capacity of the various glacial soils influences succession and determines the distribution of climaxes and individual species, especially the pines. The water-holding capacity of the soils of Itasca Park has never been adequately studied. A few determinations were presented by Lee (1924).

The writer is aware that fallaceous conclusions are often derived when one factor out of the factor complex is used alone to explain vegetational phenomena. However, Daubenmire (1936, 1937) has previously shown that in the "Big Woods" in southern Minnesota, the water-holding capacity of the soil is very critical in determining the distribution of forest species and forest types along this western edge of the summer-green forest. Eggler (1938) concluded that the lower water retaining capacity of the outwash soils in Washburn County, Wisconsin is responsible for the lack of the sugar maple-basswood climax on such soils. Corson, Allison, and Cheyney (1929) found a positive correlation between forest type and soil texture in north-eastern Minnesota. With the climate at Itasca Park rather dry and the moisture-holding capacity of the soils so variable, it was suspected that the latter might be equally as significant here.

III. Methods

The principal field work bearing on this problem consisted of the collection of soil samples from a number of representative stands of all three pines, both pure and mixed. All stands were located within the park. Lake shores, slopes, poorly drained depressions, and otherwise topographically affected places were avoided in order to restrict the significance of soils to textural characteristics.

Areas which had suffered much disturbance were avoided. Absolutely undisturbed stands, however, are not to be found in the park because of the large number of deer which congregate here.

Only those pine stands were selected where the individuals were not less than 15 cm. D.B.H., so that any possible successional tendencies would have found a fair interval of time for expression.

With respect to understory, the pine stands were classified as having no understory, or as having an understory of birch-aspen, fir-spruce-birch or sugar maple-basswood.

A floristic record of each station was taken at the time the soils were collected. All trees, above seedling size, occurring within a 3-mete radius of each core were recorded.

In each stand, 5 soil cores were collected with a minimum of 15 meters between cores. Each core represents a column of soil 6 decimeters deep, each decimeter being kept separate. The litter and duff were removed from the surface in all cases. Daubenmire's work (1937) indicates that, for water-holding capacity, the 3-6 dm. horizon of a profile is the most significant in determining the success of tree species in his region.

A total of 600 samples from 100 cores divided equally among 20 stands was obtained. Each sample was screened through a 2 mm. screen to remove skeletal material. Moisture Equivalents were determined by the Briggs and McLane (1907) method. The governor of the soil centrifuge was frequently checked by a tachometer.

TABLE 4

Showing Successional Patterns and Mean M.E.'s for Soil Stations

Sta. No.	Successional Patterns			***Mean M.E.'s of profiles		
	Pioneer*	Intermediates**	Climax	Min. for station	All pro. in station	Max. for station
1	jack pine	→ red pine (rare) →	(no evidence)	2.8	3.1	3.5
2	red pine	→	fir - spruce	2.9	3.2	4.2
3	jack pine	→ red pine →	(no evidence)	2.6	4.1	5.6
4	jack pine	→	fir - spruce	2.4	4.2	5.1
5	red pine	→	fir - spruce	3.7	5.3	6.4
6	red pine	→	fir - spruce	3.7	5.8	10.3
7	red pine	→ birch →	maple-baswood	4.0	5.9	7.1
8	red pine	→	fir - spruce	2.3	6.1	15.3
9	jack pine	→ red pine →	fir-spruce	5.3	6.9	9.1
10	white pine	→ birch-aspen →	maple-basswood	4.4	7.0	10.1
11	red & white pine	→ birch-aspen →	(no evidence)	6.0	7.6	8.9
12	jack pine	→ red & white pine →	spruce	6.2	7.8	8.8
13	jack pine	→	(no evidence)	7.1	8.0	8.7
14	jack pine	→ red & white pine →	spruce	6.2	8.3	10.3
15	jack pine	→ red & white pine →	fir-spruce	8.2	8.4	9.0
16	white pine	→ birch-aspen →	maple-basswood	8.0	10.4	14.2
17	red & white pine	→ birch? →	maple-basswood	6.2	10.5	14.0
18	red pine	→ birch-aspen →	maple-basswood	7.5	11.5	15.2
19	white pine	→ birch-aspen →	maple-basswood	4.7	14.3	25.1
20	white pine	→ birch-aspen →	maple-basswood	10.4	18.0	21.6

* The oldest trees in the mixture. The lack of evidence does not preclude the possibility that another tree community preceded these designated as "Pioneer."

** When present.

*** All means are calculated from the second to sixth decimeter horizons, inc.

IV. Results and Discussions

Several methods of presenting the Moisture Equivalent data together with the successional notes were tried, and the one used in Table 4 seemed most satisfactory. It was found that the mean Moisture Equivalent of each profile is the most significant figure, and that the distinctness of such means is more evident if the upper decimeter horizon is omitted in the calculation, since the high humus content of this stratum tends to make all the profiles more similar. The deeper horizons are the ones which constitute the chief reservoir for soil moisture on which the maturation of trees depends. For each of the 20 stands, there are given, in Table 4, the lowest mean of the 5 cores, the highest mean, and also the mean of all 5 cores. The order of arrangement of the stands is based on the latter figure.

Successional patterns as indicated in the above table are quite varied. Wherever jack pine is found, it is a pioneer. Red pine may be a pioneer, or an intermediate stage following jack pine. It can replace jack pine on soils ranging from very coarse to intermediate in texture. Occasionally some white pine is mixed with red pine following jack pine on the better soils. Pure white pine stands never follow jack pine. Birch and aspen, it may be seen, usually follow pines and precede sugar maple-basswood, but (in areas which were not studied) this association may also be the pioneer forest on burned areas.

Understories indicating the permanent or climax forests are either fir-spruce-birch or sugar maple-basswood associations. In Table 4 the horizontal line separates these climaxes almost perfectly. The fir-spruce-birch community occupies soil with lower moisture-holding capacity than sugar maple-basswood, the critical average Moisture Equivalent being between 8.4 and 10.4. The mean of all the fir-spruce-birch profiles is 5.7, that of sugar maple-basswood is 11.1. Fir-spruce-birch comes in under jack pine, or red pine, or under a mixture of red and white pines which have succeeded jack pine.

Two of the sugar maple-basswood stands studied have mean and maximum percentages lower than the upper limit of fir-spruce-birch percentages. The explanation of the distribution of these two stands may lie in strata of soil below 6 decimeters, or in soil surrounding the stands. For example, a small patch of coarse soil imbedded as a lens in a clay layer would not be so drouthy as a similar area which had access to rapid drainage. It is interesting to note that in neither case is the sugar maple-basswood following jack pine although both stands are well within the textural range of jack pine.

The distribution of the sugar maple-basswood community has a high positive correlation with pure white pine stands. The former less commonly follows a mixture of red and white, or red pine alone. No jack pine was found with sugar maple-basswood as an understory. Although there are some coarse sandy samples in the sugar maple-basswood as shown by many low percentages, somewhere within the profile there are strata of heavy loams or clays which compensate for the effects of the coarser strata. In Table 5, A is an example of such a profile in a red pine stand with sugar maple-basswood understory. B is a profile from white pine with the same understory showing a similar case. C is a profile about 15 meters distant from B in the same stand showing the extreme variability of the soil.

TABLE 5

Examples of Profiles Showing Soil Variability

Succession	Station Number	Moisture Equivalents by decimeter horizons						Mean of dm. 2-6 inc.
		1st	2nd	3rd	4th	5th	6th	
A. red pine→ birch-aspen → maple-basswood	18	13.8	12.2	9.3	7.0	6.7	14.0	9.8
B. white pine→ birch-aspen → maple-basswood	19	17.1	12.7	9.7	8.2	10.8	17.9	11.9
C. white pine→ birch-aspen → maple-basswood	19	28.8	20.0	25.1	29.8	30.2	20.6	25.1

In a few of the pine stands selected, there were no understories indicating one of the above climax types. Stations numbered 1, 3, 11, and 13 are of this class. A comparison of the Moisture Equivalents of these stands with stands having understories indicates that it is not the moisture-holding capacity of the soil that is responsible for the lack of a fir-spruce-birch understory in these stands.

In Table 6, all profiles are averaged for a species where that species occurs within three meters of the profile. Because of the wide ranges of Moisture Equivalents for each species it is extremely difficult to explain individual species preferences from a table of mean Moisture Equivalents or even from a frequency distribution table. The means for the pines are closer together than the maxima while the minima are even closer, that is, the greatest difference in these pine soils is in the upper limit of the Moisture Equivalent range. Both Table 4 and 6 agree with the conditions reported for the Cloquet Forest, Minnesota (Corson, et al. 1929), namely, soils of jack pine and red pine resemble each other more closely in water-holding capacity than either resemble that of white pine.

The means for fir, spruce, and birch are below that of white pine. This correlates with Table 4, in that these species are the climax dominants on soils ranging from very coarse to intermediate in texture, while white pine less often occurs on such soil.

On the other hand, *Acer saccharum* and *Tilia americana* as individual species seem to be more restricted to better soils than white pine. Basswood has the appearance of being more confined to clay soils than sugar maple, however, the differences in their means are due to the lack of basswood in station 7 (Table 4) where the Moisture Equivalents are exceptionally low for this type of climax. Excluding this station, sugar maple has an average Moisture Equivalent of 12.3, which is above that of basswood, and a minimum mean for a single profile of 6.0, which equals that of basswood. Farther south sugar maple appeared to occupy slightly finer soils than basswood (Daubenmire, 1937). A comparison of the Moisture Equivalents for sugar maple as given by Daubenmire and those of the present investigation shows

that, in the "Big Woods," sugar maple and basswood grow on finer soils than in Itasca Park. The average temperature for the six warmest months (April to September, inclusive) is 56.1° F. in Itasca Park, that in the "Big Woods" is about 62.3° F. (Purssell, 1934). The lower temperature of the air probably compensates for the lower moisture-retaining capacity of the soils in the more northerly region.

TABLE 6

Soil Moisture Preferences of the Pines and Climax Dominants.

Species	No. of profiles	Mean M. E. of Profiles*		
		Min.	Mean	Max.
Pinus banksiana	42	2.4	5.7	10.3
Pinus resinosa	48	2.3	6.5	15.3
Pinus strobus	41	2.9	8.3	22.7
Abies balsamea	25	2.3	6.0	25.1
Picea glauca	13	2.3	7.2	15.3
Betula papyrifera	51	2.3	8.0	21.6
Acer saccharum	27	4.0	11.3	25.1
Tilia americana	13	6.0	12.0	22.7

* All Moisture Equivalent means are calculated from the second to the sixth decimeter horizons, inclusive.

V. Summary and Conclusions

The successional patterns as diagramed in Table 4 are puzzling when considered from purely sociological aspects—why should certain of the pioneer forests follow one course of development and some another, or stated in another manner, why are the permanent forests sharply distinct and have rather diverse successional origins?

The answers to such questions are indicated by these studies of variation in the water-holding capacity of the soils. With the climate rather critical for forest species in general, and the area located in the transition between two major plant formations, the soil moisture conditions may, by slight variations, cause corresponding variations in the developmental sequence of plant communities.

The pioneers on coarse soils are jack pine and red pine. On loams, or coarser soils, containing clay strata, white pine is the characteristic pioneer. The intermediate stages, when present, vary. Red pine or a mixture of red and white pine may follow jack pine and precede the fir-spruce-birch climax. White pine usually gives way to birch-aspen which is followed by sugar maple-basswood.

The writer supports the polyclimax view: that there may be more than one climax in a region. In Itasca Park three communities are climax: ash-elm-fir on peat, sugar maple-basswood on fine-textured mineral soils, and fir-spruce-birch climax on coarse-textured mineral soils.

There are no indications of a mixture of the two climaxes on mineral soils. They may exist side by side with rather definite boundary lines. One of the

most important factors correlated with their distribution is soil moisture-holding capacity, the critical point being an average Moisture Equivalent of about 9.5 for the second through the sixth decimeter horizons in the stand. Fir-spruce-birch averages are always below this point—sugar maple-basswood almost always above it.

The polyclimax view allows the existence of edaphic physiographic, biotic, and other types of climaxes, classified on the basis of the key factor which determines the stability of the community (Nichols, 1917). The ash-elm-fir community may be called an edaphic climax on peat. Due to the lack of evidence of fir-spruce-birch or sugar maple-basswood understories at such stations as numbers 1, 3, 11, and 13 (Table 4), the writer admits the possibility that jack and red pines have been or may become edaphic climaxes. But if this is true, a factor or combination of factors other than moisture-holding capacity of the soil alone is responsible for the stability of these pines. It is theoretically possible for a pine stand, if not invaded, to maintain itself indefinitely by the establishment of seedlings only in openings due to the death of large trees. On the other hand, the complete absence of successful pine reproduction under closed forest conditions throughout the park indicates that the pines are not stable and will in the future be replaced by either fir-spruce-birch or sugar maple-basswood.

Forest plantings in this region may be made more successful by the consideration of the moisture-retaining capacity of soils. By the determination of the Moisture Equivalents and use of a table such as Table 4, the forest possibilities of upland sites may be predicted with considerable accuracy.

VI. Acknowledgments

The writer expresses deepest appreciation to those who have helped make this study possible, especially to Dr. Rexford F. Daubenmire for his suggesting the problem, for his criticisms during the progress of the research and preparation of the manuscript, for his assistance with the field work, and for his supplying the data contained in tables 1, 2, and 3.

REFERENCES

Bergman, H. F. and Harvey Stallard. 1916—The development of climax formations in northern Minnesota. Minn. Bot. Studies **4**:333-378.

Briggs, L. J. and J. W. McLane. 1907—The moisture equivalent of soils. U. S. Dept. Agr. Bur. Soils, Bull. **45**:5-23.

Clements, F. E. 1916—Plant Succession. Carnegie Inst. Wash. Pub. **242**: 512 pp.

Cooper, W. S. 1913—The climax forest of Isle Royale, Lake Superior, and its development. Bot. Gaz. **55**:1-44, 115-140, 189-235.

Corson, C. C., J. H. Allison, and E. G. Cheney. 1929—Factors controlling forest types on the Cloquet Forest, Minn. Ecology **10**:112-125.

Daubenmire, R. F. 1936—The "Big Woods" of Minnesota. Its structure and relation to climate, fire and soils. Ecol. Monogr. **6**:233-268.

———1937—Soil preferences of some upland deciduous trees in central Minnesota. Amer. Mid. Nat. **18**:367-369.

EGGLER, W. A. 1938—The maple-basswood forest type in Washburn County, Wisconsin. Ecology **19**:243-263.

GRANT, M. L. 1934—The climax forest community in Itasca Co., Minn., and its bearing upon the successional status of the community. Ecology **15**:234-257.

LEE, S. C. 1924—Factors controlling forest successions at Lake Itasca, Minn. Bot. Gaz. **78**:129-174.

NICHOLS, G. E. 1917—The interpretation and application of certain terms and concepts in the ecological classification of plant communities. Plant World **20**: 305-319, 341-353.

———1935—The hemlock-white pine-northern hardwood region of eastern North America. Ecology **16**:403-422.

PURSSELL, U. G. 1934—Climatic summary of U. S. through 1930. Sec. 44, 46. Northern Minn. U. S. D. A. Weather Bur.

STALLARD, HARVEY 1929—Secondary succession in the climax forest formations of northern Minn. Ecology **10**:476-547.

WEAVER, J. E. AND F. E. CLEMENTS. 1938—Plant Ecology. McGraw-Hill Co. 601 pp.

UNIVERSITY OF IDAHO, &
UNIVERSITY OF MINNESOTA.

The Flowering Plants of the Wichita Mountains Wildlife Refuge

Cletis T. Eskew

Introduction

This paper presents the results of a taxonomic study of the flowering plants of the Wichita Mountains Wildlife Refuge, condensed from the author's unpublished study (1936-1937).

The Wichita Mountains Wildlife Refuge is a tract of 61,480 acres, embracing the major portion of the Wichita mountains in southwestern Oklahoma, the entire area lying within Comanche County. Topographically, the area forms a range of hills which at the eastern end are rounded and in the western portions have rugged bouldery slopes. A vertical difference of nearly 1200 feet, marks the greatest relief in the area. The region has reached maturity.

Previous Collections

This is the first list of the flowering plants of the Wichita Mountains to be published.

The first person to collect plants in the Wichita Mountains Wildlife Refuge was Dr. G. G. Shumard who was with Capt. R. B. Marcy on his expedition of 1852 to the source of the North Fork of Red River. He collected about 100 plants in this region. Frank H. Rose made a grazing survey of this area in 1923. Others have made small collections at irregular intervals.

Climatic Characteristics

The summers are long and often very hot, while the winters are mild and of short duration. The annual precipitation for this region is 31.31 inches. South winds prevail, except during winter months, when the direction alternates between north and south. The average growing season is 201 days. Approximately 65 per cent of the days are clear.

Ecology of the Region

When the groves of the scrubby oaks of the Wichita Mountains are compared with the greater forest of the United States, they seem insignificant. But when compared with hundreds of square miles of treeless prairie that surround them, they take on great importance.

The forest in these mountains may be described as a mixed-oak association with a total of eight species identified by the author. The dominant is *Quercus marilandica*. Other species included: *Q. borealis* Michx., var. *maxima* Ashe, *Q. Mohriana* Rydb., *Q. Shumardii* Buckl., *Q. stellata* Wang., *Q. virginiana* Mill., *Q. macrocarpa* Michx. *Q. Muhlenbergii* Engelm., and *Q.* (a hybrid, probably *Q. marilandica* and *Q. Muhlenbergii*).

Springs and moist rocky slopes along fertile valleys provide a mesophytic habitat for plant growth. More abundant vegetation covers the northern slopes of the mountains, the valleys and along streams.

One of the most unusual disjunct plant species of this region is the western sugar maple, *Acer grandidentatum*. This Rocky Mountain plant is found nearest in the mountains of western Texas, 400 miles southwest of this Oklahoma location.

The plant communities of this region may be grouped under three main divisions; ravine, prairie, and mountain. There is every possible gradation of these zones or communities in practically all areas of the Refuge. Since the Wichita Mountains, in general, have a grassland vegetation, the prairie communities contain a larger number of striking societies than either the ravine or mountain communities.

Additions to the List of Flowering Plants of Oklahoma

No previous state record had been found for these plants:

Alopecurus carolinianus Walt.
Bouteloua rigidiseta (Steud.) Hitchc.
Bromus arvensis L.
Bromus japonicus Thund.
Eragrostis spectabilis (Pursh.) Steud.
Chloris virgata Swartz.
Cenchrus tribuloides L.
Limnodea arkansana (Nutt.) L. H. Dewey
Lesquerella repanda (Nutt.) S. Wats.
Lepidium texanum Buckl.
Rubus argutus Link.
Astragalus flexuosa (Dougl.) Rydb.
Lespedeza virginica (L.) Britt.
Gaura suffulta Engelm.
Amsonia ciliata Walt. var. *texana* (A. Gray) Coulter.
Paspalum pubiflorum Rupr.
Trichachne californica (Benth.) Chase
Tradescantia bracteata Small
Celtis laevigata Willd. var. *texana* Sarg.
Polygonum punctatum (Ell.) Small
Froelichia Drummondii Moq.
Scutellaria Brittonii Porter
Utricularia villosa Nutt. var. *americana* Gray
Artemisia serrata Nutt.
Aster commutatus Gray
Aster ericoides L.
Kuhnia suaveolens Fresen.
Othake roseum Bush.

Acknowledgments

The writer wishes to acknowledge the help of Dr. Milton Hopkins, of the University of Oklahoma, under whose directions this study was done. Charles H. Rouse, Associate Biologist of the Wichita Mountains Wildlife Refuge, gladly furnished list of plants in the Headquarters Herbarium. The author is greatly indebted to Mrs. C. T. Eskew for her assistance in collecting specimens and preparing them for the herbarium. The writer wishes to express his appreciation to the members of the department of botany in the University of Oklahoma, for their friendly criticisms and advice.

Summary of Species

Field studies and collections were made by the tuthor in the early summer of 1936 and continued during the fall of the same year and spring of 1937. Specimens of all plants were collected by the author and most of the entire collection has been deposited in the Herbarium of the University of Oklahoma. 136 species were deposited in the U. S. National Herbarium.

The list of the flowering plants contains 447 species. 75 families and 248 genera are included, 20 families are represented by only one species each.

The characteristic prairie families: Gramineae, Compositae, and Leguminosae represent the largest number of species, 174 species or 39 per cent of the total. 71 species or 15.8 per cent of the total number are Compositae, 68 species or 15.4 per cent are Gramineae, and 35 species or 7.8 per cent are Leguminosae.

Check List of the Flowering Plants of the Wichita Mountains Wildlife Refuge*

SPERMATOPHYTA

GYMNOSPERMAE

Pinaceae

Juniperus virginiana L.

ANGIOSPERMAE

MONOCOTYLEDONEAE

Typhaceae

Typha latifolia L.

Gramineae

Agrostis Elliottiana Schultes
Agrostis hyemalis (Walt.) BSP.
Alopecurus carolinianus Walt.
Alopecurus geniculatus L.
Andropogon provincialis Lam.
Andropogon saccharoides Sw.
Andropogon scoparius Michx.
Aristida dichotoma Michx.
Aristida oligantha Michx.
Aristida purpurea Nutt.
Bouteloua curtipendula (Michx.) Torr.
Bouteloua gracilis (HBK.) Lag.
Bouteloua pectinata Feath.
Bouteloua rigidiseta (Steud.) Hitchc.
Bromus arvensis L. (Introduced)
Bromus japonicus Thund.
Bromus unioloides (Willd.) HBK.
Buchloe dactyloides (Nutt.) Engelm.
Cenchrus pauciflorus Benth.
Cenchrus tribuloides L.
Chloris verticillata Nutt.
Chloris virgata Swartz.
Cynodon dactylon (L.) Pers.
Digitaria sanguinalis (L.) Scop.
Echinochloa crusgalli (L.) Beauv.
Eleusine indica (L.) Gaertn.
Elymus virginicus L.
Elymus virginicus var. *glabriflorus* (Vasey) Bush.
Eragrostis cilianensis (All.) Link.
Eragrostis curtipedicellata Buckl.
Eragrostis hypnoides (Lam.) BSP.
Eragrostis spectabilis (Pursh.) Steud.
Eragrostis trichodes (Nutt.) Nash.
Festuca elatior L.
Festuca octoflora Walt.
Hordeum pusillum Nutt.
Leersia oryzoides (L.) Sw.
Leptoloma cognatum (Schultes) Chase
Limnodea arkansana (Nutt.) L. H. Dewey
Melica nitens (Scribn.) Nutt.
Muhlenbergia capillaris (Lam.) Trin.
Muhlenbergia mexicana (L.) Trin.
Muhlenbergia racemosa (Michx.) BSP.
Panicum agrostoides Spreng.
Panicum anceps Michx.
Panicum dichotomiflorum Michx.
Panicum linearifolium Scrib.
Panicum obtusum HBK.
Panicum tennesseense Ashe.
Panicum virgatum L.
Paspalum pubescens Muhl.
Paspalum pubiflorum Rupr.
Phalaris caroliniana Walt.
Poa arachnifera Torr.
Schedonnardus paniculatus (Nutt.) Trel.
Setaria geniculata (Lam.) Beauv.
Sorghastrum nutans (L.) Nash.
Sorghum halepense (L.) Pers.
Sphenopholis obtusata (Michx.) Scribn.
Sporobolus clandestinus (Spreng.) Hitchc.
Sporobolus cryptandrus (Torr.) Gray
Sporobolus vaginiflorus (Torr.) Wood
Trichachne californica (Benth.) Chase
Triodia flava (L.) Smyth.
Triodia albescens Vasey
Triodia pilosa (Buckl.) Merr.
Uniola latifolia Michx.

* Based on the collections of the author, names according to the International Rules of Nomenclature.

Cyperaceae

Carex camporum Mackenzie
Carex vulpinoidea Michx.
Cyperus esculentus L.
Cyperus ferax Rich.
Cyperus ovularis (Michx.) Torr.
Cyperus strigosus L.
Eleocharis acuminata (Muhl.) Nees.
Eleocharis obtusa (Willd.) Schultes
Fimbristylis Vahlii (Lam.) Link.
Hemicarpha micrantha (Vahl.) Britt.
Scirpus lineatus Michx.

Commelinaceae

Commelina crispa Wooton.
Commelina erecta L.
Commelina hirtella Vahl.
Commelina virginica L.
Tradescantia bracteata Small
Tradescantia canaliculata Raf.
Tradescantia hirsutiflora Bush.
Tradescantia occidentalis (Britt.) Smyth.
Tradescantia virginiana L.

Juncaceae

Juncus aristulatus Michx.
Juncus balticus Willd. *littoralis* Engelm.
Juncus Covillei Piper.
Juncus interior Wiegand.

Liliaceae

Allium mutabile Michx.
Allium Nuttallii Wats.
Camassia esculenta (Ker.) Robin.
Nothoscordum bivalve (L.) Britt.
Smilax bona-nox L.
Smilax herbacea L.
Smilax rotundifolia L.
Yucca glauca Nutt.

Amaryllidaceae

Cooperia Drummondii Herb.

Iridaceae

Nemastylis acuta (Bart.) Herb.
Sisyrinchium gramineum W. Curtis.

DICOTYLEDONEAE

Salicaceae

Populus deltoides Marsh.
Salix longipes var. *Wardii* (Bebb.) Schneider
Salix nigra Marsh.

Juglandaceae

Carya cordiformis (Wang.) K. Koch.
Carya illinoensis (Wang.) K. Koch.
Juglans nigra L.
Juglans rupestris Engelm.

Fagaceae

Quercus borealis Michx. var. *maxima* (Marsh.) Ashe.
Quercus macrocarpa Michx.
Quercus marilandica Muench.
Quercus Mohriana Rydb.
Quercus Muhlenbergii Engelm.
Quercus Shumardii Buckl. var. *Schneckii* (Britt.) Sarg.
Quercus stellata Wang.
Quercus virginiana Mill.
Quercus (A hybrid, probably *Q. marilandica* and *Q. Muhlenbergii*)

Urticaceae

Celtis laevigata Willd.
Celtis laevigata Willd. var. *texana* Sarg.
Celtis occidentalis var. *canina* (Raf.) Sarg.
Celtis occidentalis var. *crassifolia* (Lam.) Gray
Celtis reticulata Torr.
Morus rubra L.
Ulmus americana L.
Ulmus fulva Michx.

Polygonaceae

Eriogonum annuum Nutt.
Eriogonum longifolium Nutt.
Polygonum acre HBK.
Polygonum aviculare L.
Polygonum hydropiper L.
Polygonum pennsylvanicum L.
Polygonum prolificum (Small) Robinson
Polygonum punctata? (Ell.) Small.
Polygonum ramosissimum Michx.
Rumex altissimus Wood.
Rumex crispus L.

Chenopodiaceae

Chenopodium album L.
Chenopodium album var. *viride* (L.) Moq.
Salsola kali L. var. *tenuifolia* G. F. W. Mey.

Amaranthaceae

Amaranthus retroflexus L.
Froelichia Drummondii Moq.
Froelichia floridana (Nutt.) Moq.

Phytolaccaceae

Phytolacca americana L.

Nyctaginaceae

Oxybaphus albidus (Walt.) Sweet.
Oxybaphus nyctagineus (Michx.) Sweet.

Illecebraceae

Paronychia Jamesii T. & G.
Paronychia scoparia Small.

Aizoaceae

Mollugo verticillata L.

Caryophyllaceae

Arenaria stricta Michx.
Arenaria stricta Michx. var *texana* Robinson.
Cerastium brachypodum (Engelm.) Robinson.
Silene antirrhina L.

Portulaceae

Claytonia virginica L.
Talinum rugospermum Holz.

Ranunculaceae

Anemone caroliniana Walt.
Anemone decapetala Ard.
Clematis Pitcheri T. & G.
Delphinium Penardi Huth.

Menispermaceae

Cocculus carolinus (L.) DC.

Papaveraceae

Argemone alba Lestb.
Argemone intermedia Sweet.

Fumariaceae

Corydalis aurea var. *occidentalis* Engelm.

Cruciferae

Arabis virginica (L.) Trel.
Capsella bursa-pastoris (L.) Trel.
Dithyraea Wislizeni Engelm.
Draba cuneifolia Nutt.
Erysimum asperum DC.
Lepidium bipinnatifidum Desv.
Lepidium texanum Buckl.
Lepidium virginicum L.
Lesquerella auriculata (Engelm. & Gray) S. Wats.
Lesquerella Gordoni (Gray.) Wats.
Lesquerella gracilis (Hook.) Wats.
Lesquerella ovalifolia Rydb.
Lesquerella repanda (Nutt.) Wats.
Radicula nasturtium aquaticum L.
Radicula sessiliflora (Nutt.) Greene.
Sisymbrium canescens Nutt.

Capparidaceae

Cleome serrulata Pursh.

Crassulaceae

Sedum Nuttalianum Raf.
Sedum pulchellum Michx.

Grossulariaceae

Ribes aureum Pursh.

Rosaceae

Crataegus Stevensiana Sarg.
Geum canadense Jacq.
Geum virginianum L.
Potentilla arguta Pursh.
Prunus americana Marsh.
Prunus angustifolia Marsh.
Prunus mexicana Wats.
Prunus virginiana L.
Rubus argutus Link.

Leguminosae

Acacia angustissima (Mill.) Ktze.
Amorpha canescens Pursh.
Amorpha fruticosa L.
Amorpha microphylla Pursh.
Astragalus caryocarpus Ker.
Astragalus flexuosa (Dougl.) Rydb.
Astragalus plattensis Nutt.
Baptisia australis (L.) R. Br.
Baptisia bracteata (Muhl.) Ell.
Baptisia Nuttalliana Small.
Cassia chamaecrista L.
Cercis canadensis L.
Clitoria mariana L.
Desmanthus illinoensis (Michx.) MacM.
Desmodium grandiflorum (Walt.) DC.
Desmodium obtusum (Muhl.) DC.
Desmodium sessilifolium (Torr.) T. & G.
Gymnocladus dioica (L.) Koch.
Hoffmanseggia falcaria Cav.
Hosackia americana (Nutt.) Piper.
Indigofera leptosepala Nutt.
Krameria secundiflora DC.
Lespedeza virginica (L.) Britton.
Neptunia lutea (Leavenw.) Benth.
Parosela aurea (Nutt.) Britt.
Petalostemum candidum Michx.
Petalostemum purpureum (Vent.) Rydb.
Prosopis juliflora (Sw.)
Psoralea cuspidata Pursh.
Psoralea tenuiflora Pursh.
Robinia pseudo-acacia L.
Scrankia uncinata Willd.
Vicia americana var. *angustifolia* Nees.
Vicia ludoviciana Nutt.
Vicia micrantha Nutt.

Linaceae

Linum multicaule Hook.
Linum rigidum Pursh.
Linum sulcatum Riddell.

Oxalidaceae

Oxalis stricta L.
Oxalis violacea L.

Geraniaceae

Geranium carolinianum L.

Zygophyllaceae

Tribulus terrestris L.

Rutaceae

Ptelea trifoliata L.

Polygalaceae

Polygala alba Nutt.

Euphorbiaceae

Croton capitatus Michx.
Croton texensis (Klotzsch.)
Euphorbia dentata Michx.
Euphorbia dictyosperma Fisch. and Mey.
Euphorbia maculata L.
Euphorbia marginata Pursh.
Stillingia sylvatica L.
Tragia ramosa Torr.

Anacardiaceae

Rhus canadensis var. *serotina* Palmer & Steyermark.
Rhus copallina L.
Rhus glabra L.
Rhus toxicodendron L.

Aceraceae

Acer grandidentatum Nutt.

Sapindaceae

Sapindus Drummondii H. & A.

Vitaceae

Cissus ampelopsis Pers.
Cissus incisa (Nutt.) Des Moulins.
Parthenocissus quinquefolia (L.) Planch.
Vitis cinerea Engelm.
Vitis cordifolia Michx.
Vitis rotundifolia Michx.
Vitis rupestris Scheele.
Vitis vulpina L.

Malvaceae

Callirrhoe involucrata (T. & G.) Gray.
Callirrhoe pedata Gray.
Malvastrum coccineum (Pursh.) Gray.

Violaceae

Hybanthus verticillata (Ort.) A. Nels.
Viola papilionacea Pursh.
Viola Rafinesquii Greene.

Loasaceae

Mentzelia oligosperma Nutt.

Cactaceae

Echinocereus Baileyi Rose.
Echinocereus caespitosus Engelm. & Gray.
Opuntia humifusa Raf.

Lythraceae

Ammannia coccinea Rott.
Lythrum lanceolatum Ell.

Onagraceae

Gaura biennis L.
Gaura coccinea Pursh.
Gaura suffulata Engelm.
Jussiaea diffusa Forskal.
Ludvigia palustris (L.) Ell.
Oenothera laciniata Hill.
Oenothera laciniata var. *grandiflora* (Walt.) Robinson
Oenothera missouriensis Sims.
Oenothera missouriensis Sims. var. *incana* Gray.
Oenothera rhombipetala Nutt.
Oenothera serrulata Nutt.
Oenothera speciosa Nutt.
Oenothera trilobata Nutt.
Stenosiphon linifolius (Nutt.) Britton.

Umbelliferae

Cynosciadium pinnatum DC.
Eryngium Leavenworthii (T. & G.) Britton.
Lomatium daucifolium (Nutt.) Coult. & Rose.
Ptilimnium Nuttallii (DC.) Britton.
Sanicula canadensis L.

Cornaceae

Cornus asperifolia Michx.

Sapotaceae

Bumelia lanuginosa (Michx.) Pers.

Oleaceae

Fraxinus americana L.
Fraxinus pennsylvanica Marsh.
Fraxinus pennsylvanica Marsh. var. *lanceolata* (Borkh.) Sarg.

Gentianaceae

Sabatia angularis (L.) Pursh.
Sabatia campestris Nutt.

Apocynaceae

Amsonia ciliata Walt. var. *texana* (Auth.)
Amsonia tabernaemontana Walt.

Asclepiadaceae

Acerates angustifolia (Nutt.) DC.
Acerates viridiflora Ell.
Asclepias pumila (Gray.) Vail.
Asclepias stenophylla Gray.
Asclepias Sullivantii Engelm.
Asclepias tuberosa L.
Asclepias verticillata L.
Asclepiodora decumbens (Nutt.) Gray.
Asclepiodora viridis (Walt.) Gray.

Convolvulaceae

Convolvulus incanus Vahl.
Cuscuta Coryli Engelm.
Evolvulus argenteus Pursh.
Evolvulus pilosa Nutt.
Ipomoea longifolia Benth.

Polemoniaceae

Gilia rubra (L.) Heller.
Phlox pilosa L.

Hydrophyllaceae

Phacelia congesta Hook.
Phacelia dubia (L.) Small.
Phacelia hirsuta Nutt.

Boraginaceae

Lithospermum angustifolium Michx. (L.)
Lithospermum mandanense Spreng.
Myosotis virginica (L.) BSP. var. *macrosperma* (Engelm.) Fernald
Onosmodium occidentale Mackenzie.

Verbenaceae

Lippia cuneifolia (Torr.) Steud.
Verbena bipinnatifida Nutt.
Verbena bracteosa Michx.
Verbena canadensis (L.) Britton.
Verbena pumila Rydb.
Verbena stricta Vent.

Labiatae

Hedeoma ciliata Nutt.
Monarda dispersa Small.
Monarda fistulosa L.
Monarda pectinata Nutt.
Monarda punctata L.
Salvia azurea Lam. var. *grandiflora* Benth.
Salvia lanceaefolia Poir.
Scutellaria Brittonii Porter.
Scutellaria Wrightii Gray.
Teucrium canadense L.

Solanaceae

Physalis lobata Torr.
Solanum carolinense L.
Solanum elaeagnifolium Cav.
Solanum rostratum Dunal.

Scrophulariaceae

Castilleja sessiliflora Pursh.
Collinsia violaceae Nutt.
Linaria canadensis (L.) Dumont.
Penstemon albidus Nutt.
Penstemon Cobaea Nutt.
Penstemon tubiflorus Nutt.

Lentibulariaceae

Utricularia biflora Lam.
Utricularia villosa Nutt. var. *americana* Gray.

Acanthaceae

Ruellia ciliosa Pursh.
Ruellia pedunculata Torr.

Phrymaceae

Phryma leptostachya L.

Plantaginaceae

Plantago aristata Michx.
Plantago occidentalis DC.
Plantago Purshii R. & S.
Plantago rhodosperma Dcne.
Plantago spinulosa Dcne.
Plantago virginica L.
Plantago Wrightiana Dcne.

Rubiaceae

Cephalanthus occidentalis L.
Galium aparine L.
Galium triflorum Michx.
Houstonia angustifolia Michx.
Houstonia minima Beck.

Caprifoliaceae

Symphoricarpos orbiculatus Moench.
Viburnum rufidulum Raf.

Valerianaceae

Valerianella radiata (L.) Dufr.

Cucurbitaceae

Cucurbita foetidissima HBK.
Cyclanthera dissecta (T. & G.) Arn.

Campanulaceae

Specularia leptocarpa (Nutt.) Gray
Specularia perfoliata (L.) DC.

Lobeliaceae

Lobelia leptostachys DC.

Compositae

Achillea lanulosa Nutt.
Achillea Millefolium L.
Actinea linearifolia (Hook.) Kuntze.
Actinea scaposa (Nutt.) Kuntze.
Ambrosia artemisiifolia L.
Ambrosia psilostachya DC.
Ambrosia trifida L.
Amphiachyris dracunculoides (DC.) Nutt.
Aplopappus ciliatus (Nutt.) DC.
Artemisia gnaphalodes Nutt.
Artemisia kansana Britt.
Artemisia serrata Nutt.
Aster commutatus Gray
Aster ericoides L.
Aster oblongifolium Nutt.
Baccharis salicina T. &. G.
Berlandiera texana DC.
Brauneria angustifolia (DC.) Heller.
Centaurea americana Nutt.
Chaetopappa asteroides DC.
Gutierrezia Sarothrae (Pursh.) Britt. & Rusby.
Helenium autumnale L.
Helenium badium (Gray) Greene
Helenium tenuifolium Nutt.
Helianthus annuus L.
Helianuthus hirsutus Raf.
Helianthus Maximiliani Schrad.
Helianthus petiolaris Nutt.
Hymenopappus corymbosus T. & G.
Hymenopappus tenuifolium Pursh.
Kuhnia eupatorioides L. var. *corymbulosa* T. &. G.
Kuhnia suaveolens Fresen.
Lactuca pulchella (Pursh.) DC.
Lepachys columnaris (Sims.) T. & G.
Liatris punctata Hook.
Chrysopsis pilosa Nutt.
Chrysopsis stenophylla (Gray) Greene
Chrysopsis villosa Nutt.
Chrysopsis villosa Nutt. var. *canescens* Gray.
Cirsium undulatum (Nutt.) Spreng.
Coreopsis grandiflora Hogg.
Coreopsis lanceolata L. var. *villosa* Michx.
Coreopsis tinctoria Nutt.
Coreopsis verticillata L.
Engelmannia pinnatifida T. &. G.
Erigeron bellidiastrum Nutt.
Erigeron divergens T. & G.
Erigeron ramosus (Walt.) BSP.
Evax multicaulis DC.
Evax prolifera Nutt.
Gaillardia pulchella Foug.
Gaillardia suavis (Gray) Britt. & Rusby.
Grindelia nuda Wood.
Grindelia squarrosa (Pursh.) Dunal.
Othake roseum Bush.
Pyrropappus carolinianus (Walt.) DC.
Rudbeckia hirta L.
Senecio plattensis Nutt.
Senecio Riddellii T. & G.
Sideranthus spinulosus (Pursh.) Greene.
Solidago Boottii Hook.
Solidago missouriensis Nutt.
Solidago mollis Bartl.
Solidago radula Nutt.
Taraxacum vulgare (L.) Schrank.
Thelesperma gracile (Torr.) Gray.
Thelesperma trifidum (Poir.) Britt.
Vernonia missourica Raf.
Xanthisma texanum DC.
Xanthium pennsylvanicum Wallr.
Xanthium speciosum Kearney.

REFERENCES

BULL, ROTHA Z. 1932—Vascular plants of Greer County, Oklahoma Unpubl. thesis, Univ. Okla.

CLARK, ORA M. 1934—The Cacti of Oklahoma. Proc. Oklahoma Acad. Sci. **14**:34-36.

ESKEW, C. T. 1937—The flowering plants of the Wichita National Forest. Unpubl. thesis, Univ. Okla.

HOFFMAN, M. G. 1930—Geology and petrology of the Wichita Mountains. Okla. Geol. Surv. Publ. Bull. No. **52**:83 p.

JEFFS, R. E. AND ELBERT L. LITTLE, JR. 1930—A preliminary list of the ferns and seed plants of Oklahoma. Univ. Okla. Biol. Surv. Publ. **2**:39-101.

MARCY, R. B. 1852—Exploration of the Red River of Louisiana, in the year 1852. 33d. Cong., 1st. ses., House Ex. Doc. 15. 286 p. Washington 1854. Appendix G. Description of the plants collected during the expedition: by Dr. J. Torrey, p. 247-272.

WAHLGREN, H. F. 1936-1937—Climatological data. United States Department of Agriculture. Weather Bureau. Okla. City.

MANGUM, OKLA.

A Morphological Study of the Leaf and Tendril of Passiflora caerulea

Virginia B. Gangstad

No studies of the internal anatomy of either leaf or tendril have been made. This paper presents the details of these two structures as demonstrated by the use of lactic acid. This technique was suggested by Professor J. T. Buchholz and it proved a very satisfactory procedure.

E. Strasburger (1897) gives a formula for the preparation of lactophenol, but in this investigation lactic acid without the phenol gave the desired results.

Material and Method

Passiflora caerulea L. was obtained from the plant physiology greenhouse of the University of Illinois.

Nodes in various stages of development were dissected from the plant, placed in a petri dish, covered with 85 per cent lactic acid, and allowed to stand for three to six months or longer. To hasten the clearing process the petri dishes were covered and placed in an oven maintained at 55° C. The lactic acid renders the material transparent and the vascular bundles appear as dark lines under the binocular dissecting microscope. Therefore, it is very easy to trace the vascular system. Drawings were made with the aid of a camera lucida.

Origin and Anatomy of the Leaf and Tendril

The blade of the leaf is three-lobed, simple, palmately net-veined with three principal vascular bundles. On the lower portion of the petiole are two glands opposite one another, also at the base of the petiole are two stipules which appear early and for a short time are larger and more conspicuous than the blade. A tendril is located in the axil of each leaf.

The leaf originates as a simple protuberance on the growing stem apex (Fig. 1, c). Then small lateral stipules appear as humps on the base of the leaf (Fig. 1, j). Soon the blade develops two lateral lobes (Figs. 2, 3, 9). At this stage the first vascular tissue is visible in the median expanded portion of the leaf (Fig. 2, o), also two primary lateral bundles (Fig. 2, o). Later these three bundles (Fig. 2, s, o, p) extend downwards into the main stem axis. The median bundle (Fig. 3, o) develops two secondary lateral branches (Fig. 3, z, x) which extend into the other two lobes of the leaf, also at this stage bundles which originate in the stipules (Fig. 3, v, t) grow downward and join the primary lateral bundles (Fig. 3, s, p). The leaf forms a semi-circular sheath around the stem axis. The primary lateral bundle (Fig. 4, s)

fuses with the nearest secondary lateral branch (Fig. 4, z), while the second primary lateral bundle (Fig. 4, p) fuses with the other secondary lateral branch (Fig. 4, x), establishing a closed leaf vascular system. More bundles develop in the stipules so that each stipule has three main bundles (Fig. 5). The bundles from each stipule fuse with a primary lateral strand (Fig. 5, s, p).

As the leaf matures, each secondary lateral bundle forks (Fig. 6, x, z), one arm going into the lateral lobe and the other fusing with the median bundle (Fig. 6, o). Fig. 7 shows an elaboration of the fundmental system of the leaf already described.

The tendril has been a morphological problem of long standing and its structure has been variously interpreted by investigators:

Hugo Mohl (1827) conceived the tendril as a metamorphosed flower peduncle.

H. Wydler (1852-77) considered the tendril as a branch which bears a bract at its base. In the axil of this bract another axis is formed which terminates in a flower.

M. T. Masters (1879) interpreted the tendril as a flowerless subdivision originating from the same growing point as the peduncle of the flower. He thought that the meristematic protruberance in the axil of the leaf divides dichotomously, one tip developing into the tendril and the other into the flower.

G. Dutailly (1875) reported that the tendril is an outgrowth of the vegetative bud in the axil of the leaf. But this investigator has confused the primordia in the axil of the leaf, therefore, his results are unreliable.

C. Darwin (1867) thought that the tendril is a side shoot from the flower peduncle.

O. Hagerup (1930) considers the tendril a metamorphosed branch.

In *P. caerulea* a meristematic protuberance appears (Fig. 8, g) in the axil of the leaf. This protuberance forks (Fig. 9, d, h) one division forming the tendril and the other a flower bud (Fig. 10, d, h) which is in accordance with the investigations of M. T. Masters (1879).

In the development of the embryonic tendril and flower, the xylem differentiates first just below the flower in the node (Fig. 4, w). Soon this vascular strand, the axillary bundle, (Fig. 4, w) grows downward and joins the vascular cylinder of the stem, also it extends upward and forks dichotomously, one branch going into the tendril (Fig. 5, m) and the other into the flower peduncle (Fig. 5, d). This primary tendril strand (Fig. 5, m) is the first of a group of tendril bundles; likewise the primary flower strand (Fig. 5, d) is the first of a group of flower bundles. Later as shown in Fig. 5, k a second tendril strand differentiates in the tendril and develops downward into the

FIGURES

1. Shoot apex (a) showing origin of the first foliage leaf (c), second one with blade (f) and stipules (j). 94x

2. Shows leaf in which the earliest differentiation of xylem occurs. (o) median bundle, (s,p) primary lateral bundles. 94x

3. Later stage shows that the median strand has developed two branches (z, x). Stipular bundles (v, t) have differentiated. 94x

4. Young node showing the origin of the axillary bundle (w). 94x

5. Later stage showing axillary bundle has forked one branch (m) extends into the tendril, and the other (d) into the flower. Second tendril strand has differentiated (k). 32x

6. Diagram of the vascular anatomy of a node showing the second tendril strand (k) extending downward into stem. Laterals (x, z) have forked, the inner branches have fused with the median bundle and the outer forks supply the blade lobes. 32x

7. Diagram of a later nodal stage showing the tendril bundles converged into a group bundle (k) the primary tendril bundle (m), the flower bundle (d), and the axillary bundle (w). 27x

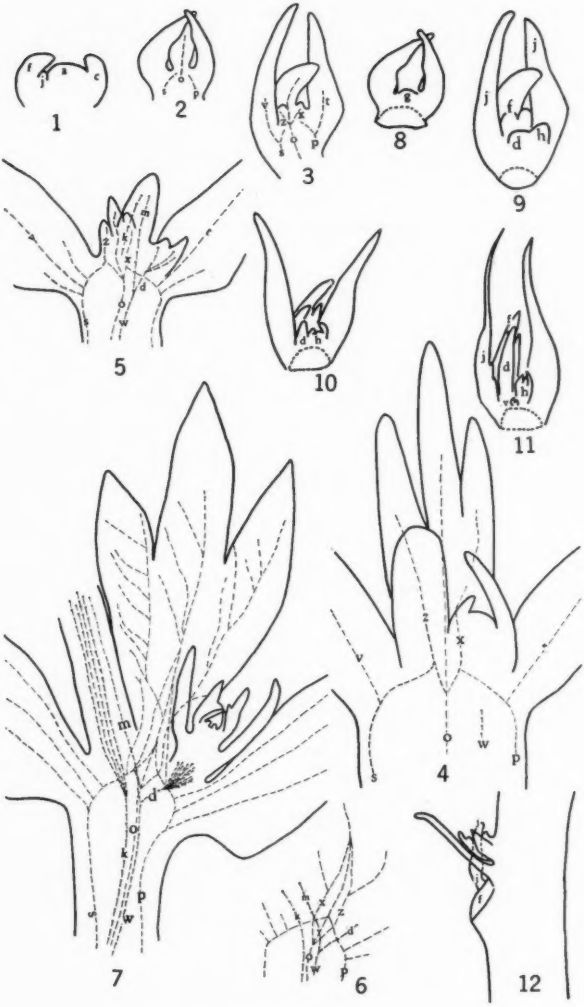
8. Very young node with the axillary meristematic protuberance (g) which will form the tendril and flower. 94x

9. Diagram of a later stage showing the meristem divided into two growing tips one of which will develop into a tendril (d), and the other into a flower, (h.) Stipules (j) and leaf blade (f) are indicated. 94x

10. Later stage in which the axillary protuberances can be recognized definitely as tendril (d) and flower (h). 27x

11. Node showing vegetative bud (v). 12x.

12. Longitudinal diagram of node of *P. incarnata* seedling showing a vegetative bud (v), tendril (d), stipule (j), and leaf scar (f). No flower but is formed. 12x


1
2
3
8
9
5
10
11
4
7
6
12

stem (Fig. 6 k). Meanwhile the tendril primordium has grown in length so that a long slender tendril is formed. Subsequently three other bundles appear in the tendril, converge at the node with the second tendril bundle (Fig. 7, k), and form a group bundle which extends down into the stem. The primary tendril strand (Fig. 7, m) remains a part of the axillary bundle which now has become a group bundle consisting of strands from the flower and from the tendril (Fig. 7, w). In the node of the young leaf five principal bundles are present, three of which supply the leaf, one the flower, and the fifth the tendril (Fig. 7). The tendril continues to elongate, resulting in a structure which is straight for a short distance at the base and then curls and twists corkscrew-like. The many vascular strands in the mature tendril form an ectophloic siphonostele, so that the tendril is typically a stem structure.

Early in the development of the flower, tendril, and leaf, a small vegetative bud forms in the axil of the leaf in front of the flower and tendril (Figs. 11, v, 12, v).

An examination of the seedlings of *P. caerulea* showed a tendril and a small vegetative bud (Fig. 12, v) in the leaf axis in the first eight to eleven nodes. In the following nodes the flower appeared. However, not all species agree with *P. caerulea* for in green house seedlings of *P. incarnata* L. only vegetative buds were present in the axils of the first eight leaves. The succeeding nodes bear a meristematic protuberance which develops without forking into the tendril as in the first nodes of *P. caerulea*.

The author wishes to thank Dr. J. T. Buchholz and Dr. Stella M. Hague for their help.

REFERENCES

DARWIN, C. 1867—On the Movements and Habits of Climbing Plants. Jour. Linn. Soc. **9**:1-118.

DUTAILLY, G. 1875—Recherches anatomique et organogénétiques sur les Cucurbitacées et les Passifloraceae. Ass. Franc. Avanc. Sci. Montpelier (Abstract from 3).

HAGERUP, O. 1930—Vergleichende morphologische und systematische Studien über die Ranken und andere vegetative Organe der Cucurbitaceen und Passifloraceen. Dansk Bot. Arkiv **6**:1-103.

MASTERS, M. T. 1879—Contributions to the natural history of Passifloraceae. Transact. Linn. Soc. London **27**:593.

MOHL, H. 1827—Ueber den Bau und das Winden der Ranken und Schlingpflanzen. (Abstract from 3).

STRASBURGER, E. 1897—Das Botanische Practicum. Jena. p. 692.

WYDLER, H. 1852—Über einige Eigenthümlichkeiten der Gattung Passiflora. Mitth. d. Bern. Naturh. Ges. No. 243 u. 244. (Abstract from 3).

UNIVERSITY OF ILLINOIS,
URBANA, ILLINOIS.

Note on a Lepidophyte Strobilus Containing Large Spores, from Braidwood, Illinois

Chester A. Arnold

The specimen described here is a portion of a compressed strobilus in a small nodule which was discovered by Mr. Leroy Harvey, student at the University of Michigan, on a strip mine dump between Braidwood and Coal City, Illinois, in May, 1937. The coal beds in the vicinity of Braidwood are of Carbondale (Allegheny) age, and the associated plant-bearing nodules are similar in age and appearance to those from the well known fossil locality at Mazon Creek. The specimen is of special interest because the megaspores which are retained within the megasporangia are distinctive, and may be readily recognized in the isolated condition.

The strobilus, for which the name *Lepidostrobus braidwoodensis* sp. nov., is proposed, is 14 mm. wide and about 35 mm. long, although the base and apex are lacking (Fig. 1). No mineralization of the tissues had taken place so most of the structural details of the axis and sporophylls had disappeared. The only parts that may be studied satisfactorily are the very large megaspores which are heavily cutinized and have been retained in approximately their original positions within the compressed cone.

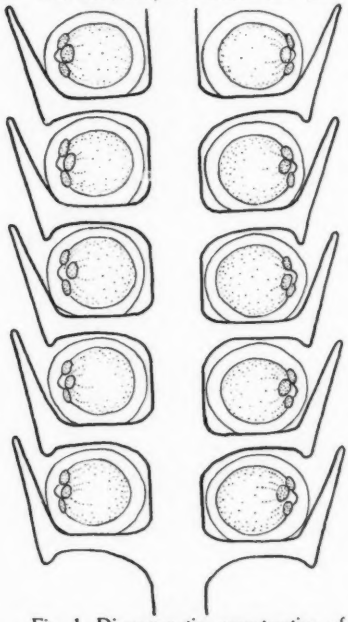


Fig. 1. Diagrammatic reconstruction of *Lepidostrobus braidwoodensis* showing the large mature megaspores borne singly in the megasporangia. The axis and sporophylls have been restored. x3½.

The spores were prepared for study by treating fragments of the cone with a mixture of hot concentrated nitric acid and potassium chlorate. After maceration, the spores were washed in 95% alcohol and mounted in diaphane. This schedule not only secured spores free from all extraneous material, but rendered them sufficiently transparent so that the details of the exine could be successfully photographed.

Each megasporangium contains one large megaspore and three aborted ones. It was possible to remove a few of the large megaspores with one or more of the aborted members still

in position around the apex of the mature spore (Figs. 2 and 3). From this, as well as from the position of the large spores in the compression, it is evident that but a single functional megaspore tetrad developed in the megosporangium, and from this only one megaspore reached maturity.

The axial diameter of the mature megaspore is slightly longer than the equatorial diameter, but because of longitudinal and cross folding of the exine as a result of compression, the exact diameter of a mature spore is difficult to determine. After allowing for these discrepancies, the axial diameter seems slightly to exceed 2 mm. whereas the equatorial diameter is slightly less (Figs. 2 and 5). The aborted spores are less than .5 mm. with the equatorial diameter slightly less than the axial (Fig. 4). The position of the apex of the mature spore in the cone shows that the spore to mature was toward the axis and those to become aborted were directed toward the distal end of the sporophyll (Fig. 1). The three aborted members, however, did undergo a certain amount of enlargement before the fourth one gained complete ascendency, as is shown by the relatively small area of the proximal surfaces between the segments of the triradiate ridge (Fig. 4).

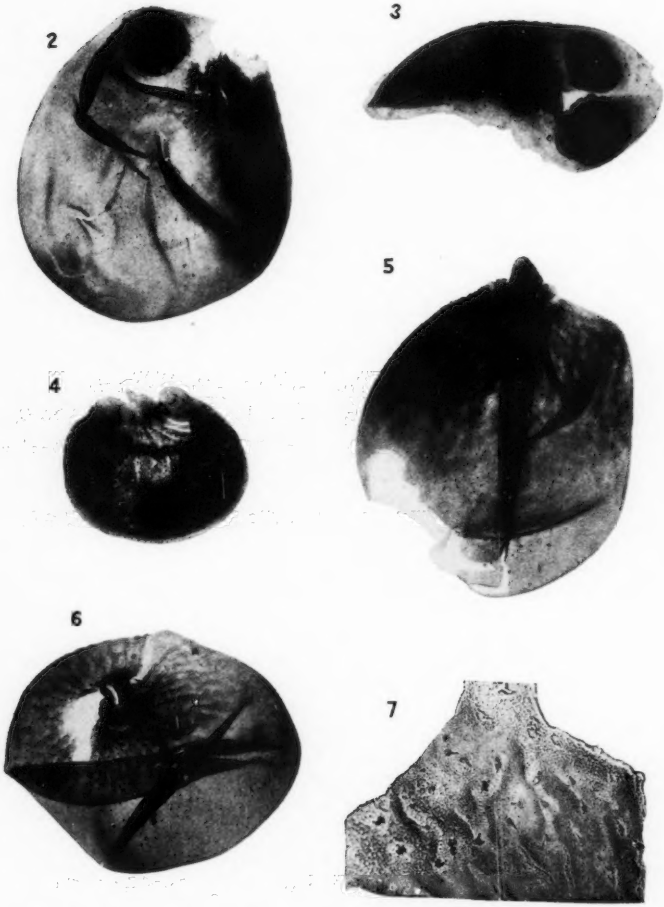
The enlargement of the functional megaspores had so altered the original tetrahedral pattern that the triradiate ridge and the proximal faces became distorted. At the apex of the spore is a blunt beak (Figs. 5 and 6) which seems to be thrown into three folds probably corresponding to the original segments of the triradiate ridge. Details of this, however, are obscure. Extending backward from the apex is a series of shallow undulating folds reaching about half way to the equatorial plane. These folds may also be seen about the apex of the aborted spores (Fig. 4). The remaining part of the spore surface which appears smooth under low magnification is ornamented with very small spines which are readily distinguishable under high magnification. These spines, which seem to characterize this spore, are minute projections about 14 micra in length surmounting a swollen or bulbous base, the combined height being only 27 micra (Fig. 7).

The megaspores of *L. braidwoodensis* belong to the Lagenicula group of *Triletes*, the members of which are defined by Bennie and Kidston* as "oval or circular with a neck-like projection, the outer surface smooth or with bristle-like hairs." The agreement of *L. braidwoodensis* is closest to Bennie and Kidston's variety *major* which is from 1½ to 2 mm. in diameter. The type form of Lagenicula is slightly larger than 1 mm.

Two similar *Lepidostrobi* containing megaspores of the Triletes-Lagenicula type and in which only one mature megaspore occupies the megasporangium are reported by Bocheński.** In one of these, *L. major*, the mature spore has been identified as *Triletes giganteus*. *T. giganteus* is as much as 1 cm. long, which is larger than the megaspore of *L. braidwoodensis*. The undeveloped

* Bennie, J. and R. Kidston. On the Occurrence of Spores in the Carboniferous Formation of Scotland. Proc. Roy. Phys. Soc. Edinburgh **9**:82-117. 1886.

** Bocheński, T. Über Sporophyllstände (Blüten) einiger Lepidophyten aus dem produktiven Karbon Polens. XII. Jahrg. Pol. Geol. Gesell.: 193-240. 1936.



Figs. 2-7. Megaspores (Triletes-Lagenicula) of *Lepidostrobus braidwoodensis* sp. nov. Fig. 2. Mature megaspore with one aborted megaspore of the original tetrad in approximately the original position. x 25. Fig. 3. Apical view of fragment of mature megaspore with two aborted spores in place. x25. Fig. 4. Aborted megaspore showing apical foldls of the exine. x58. Fig. 5. Side view of large megaspore showing apical crest. x25. Fig. 6. Apical view of large megaspore showing the undulating ridges extending backward from the apex. x25. Fig. 7. Portion of exine showing the small spinose appendages situated upon swollen bulbous bases x82.

members of the tetrad are also present in the megasporangium. In the other form, *L. Bohdanowiczii,* the megaspore is smaller than in *L. major,* but slightly larger than in *L. braidwoodensis.* Also it has an axial diameter greater than the equatorial, but the most apparent difference is that the apex of the spore of *L. Bohdanowiczii* is directed toward the axis instead of away from it as in *L. major* or *L. braidwoodensis.*

Scott*** believed that the Triletes-Lageniculae of Bennie belong to *Lepidostrobus veltheimianus* although actual proof of connection is apparently lacking. *L. veltheimianus,* however, differs markedly from *L. braidwoodensis* in that the megasporangia contain eight to sixteen megaspores.

Although there exists a wealth of information concerning the internal structure of numerous species of *Lepidostrobus,* the relation between the various species and the numerous lepidodendroid spore forms of the *Triletes* type is not so well known. Most of the spores observed *in situ* in the megasporangia of *Lepidostrobus* have seen only in thin sections which do not include entire spores, and as a consequence the surface features often escaped attention. Since morphological studies of *Lepidostrobus* have centered mainly around the structure of the axis and the sporophylls, the significance of the relation between structure and spore form has been considerably overlooked. The advantages of the maceration technique have not been fully appreciated in investigating the structure of *Lepidostrobus.* If the conventional thin sections were to be supplemented with preparations of macerated material, many structural features wihch ordinarily escape notice would be observed.

Lepidostrobus is ordinarily regarded as a fructification bearing several megaspores in the megasporangium. The Triletes-Lageniculae, however, apparently represent a distinct evolutionary trend among the Paleozoic Lepidodendrales toward a reduction in megaspore number with a corresponding increase in spore size. The height of development was attained by *Lepidocarpon* where the single large megaspore was retained and protected by the integument-like outgrowth of the megasporophyll, with the consequent formation of a seed-like organ. The Triletes-Lageniculae of the type produced by *L. braidwoodensis,* however, were free-sporing, as indicated by the heavily cutinized wall, and the ease with which they may become separated from the sporangia. Forms like *L. braidwoodensis* which bear but one large functional spore are probably intermediate types standing somewhere between the numerous many-spored forms which are commonly regarded as "typical," and the highly specialized *Lepidocarpon* type.

*** Scott, D. H. Studies in Fossil Botany, Pt. II, 3rd Ed. p. 166, 1920.

University of Michigan,
Ann Arbor, Michigan.

Notes and Discussion

PITUOPHIS AND SCAPHIOPUS IN INDIANA

Paul L. Swanson

The possibility of the occurrence of *Pituophis sayi sayi* (Schlegel) has been mentioned by the writers on Indiana herpetology, but as far as we can discover, no one has had an actual record. David C. Swanson, who has spent some five years in Indiana as forester with various CCC Camps, has collected a number of specimens on the Jasper-Pulaski Game Reserve near Medaryville.

Elaphe vulpina (Baird and Girard) is abundant in the same locality, and both of these large serpents are locally known as Bull Snakes; indiscriminately by most. We have kept a number of specimens alive for exhibition purposes, and retained only one as a matter of record, which is now Carnegie Museum specimen No. 9750. This specimen was caught on the Game Reserve during the summer of 1935. We believe that this is the easternmost record for this species to date.

To the best of our knowledge, no one has even mentioned the probability of *Scaphiopus holbrookii holbrookii* (Harlan) in Indiana. Hence its discovery is of interest as it adds another species to the herpetological fauna of the state, as well as another genus and family.

On May 3, 1937 while we were driving along U.S. Route 50 four miles west of Shoals, we heard the Spadefoots calling by the thousands. They floated with legs outstretched in the rain water pools in the low-lying fields adjacent to the White River. Twenty of them were collected in forty minutes. Although we collected extensively for three seasons in southern Indiana, this was the only time and place we observed this species. The Carnegie Museum has part of those collected as Nos. 13,450-61.

Polk, Pennsylvania.

Sectional Issuance of Biological Abstracts
Plan for 1939

Fifteen years ago American biologists became convinced that the mounting periodical literature of the subject had to be brought under better control. It was more than any library could acquire, more than any person could read. Hence the organization of *Biological Abstracts*, now in its twelfth annual volume. However, this publication has a fatal weakness. The Union of American Biological Societies that gave it being was only a paper union. There was neither association nor revenue.

Thanks to mighty friends it found, outstanding among these the Rockefeller Foundation which contributed nearly three quarters of a million dollars, *Biological Abstracts* had a period of maximum prosperity. But in the end there were only 2000 subscribers, two-thirds of them institutional; just enough to meet 40 percent of the outlay. With the necessary close of Foundation financing in 1937 the problem became acute. The generosity of subsidizing institutions and fine patronage from abroad, under an emergency arrangement of scaled charges, has prevented suspension during 1938 and provided the opportunity of working out a permanent plan for 1939. Such a plan is here presented in confident belief that it will give general satisfaction, make the *Abstracts* fully self-supporting and enable it to extend its service.

One of the prime objectives in the initiation and development of *Biological Abstracts* has related to its important role in integrating the findings of science in an age where specialization is the watchword. In spite of this rather obvious and generally desirable goal there has been a constant undercurrent, and in some quarters a rather insistent demand, for a return to the specialized type of abstract journals, or for a printing of *Biological Abstracts* in separate parts so that opportunity would be afforded those so desiring, to subscribe to the group of subjects in which they, individually, were most interested. Many reasons for this viewpoint have, from time to time, been offered, chief among them being a logically assumed reduction in cost for a part as compared with the whole.

Both these viewpoints are perfectly legitimate and understandable, and the problems thereby presented are surely worthy of every effort toward ultimate solution—so long as the general end in view is the highest good to the greatest number.

In the endeavor to meet the situation satisfactorily, a plan has been evolved whereby *Biological Abstracts*, while continuing to appear as a single complete entity, might, without repaging or other change except in the cover, be also broken up into several subject groups which would be made available to individuals not desiring the complete service. The idea seems practicable and the following subject grouping into five "reprint" parts is adopted for 1939.

I. *Abstracts of General Biology* to include General Biology, Biography-History, Bibliography, Evolution, Cytology, Genetics, Biometry, and Ecology; price $4.

II. *Abstracts of Experimental Animal Biology* to include Animal Physiology, Nutrition, Pharmacology, Pathology, Anatomy, Embryology and Animal Production; $9.

III. *Abstracts of Microbiology and Parasitology* to include Immunology, Bacteriology, Viruses, Parasitology, Protozoology, and Helminthology; $5.

IV. *Abstracts of Plant Sciences* to include Phytopathology, Plant Physiology,

Plant Anatomy, Paleobotany, Systematic Botany, Agronomy, Horticulture, Forestry, Pharmacognosy, and Pharmaceutical Botany; $6.

V. *Abstracts of Animal Sciences* to include Paleozoology, Parasitology, Protozoology, and Helminthology, Systematic Zoology, and Economic Entomology; $6.

The subscription price for the complete volume 13 for 1939 will be $25 to individual subscribers and institutions alike.

A plan of this nature would involve merely the lifting out (without resetting of type or renumbering of the abstracts) of the sections appertaining to the subject group concerned and binding them in a separate cover which would bear the appropriate subtitle. This provedure would undoubtedly be facilitated by rearrangement of some of the sections. The complete index, going to *all* subscribers, would still preserve most of the desirable long-range features of the full service, and especially so since all subscribing libraries and institutions will, of course, want *Biological Abstracts* in its entirety. This would meet the requirements alike of specialization and general survey at prices that will be found feasible by both biologists and libraries. It is most emphatically not proposed to destroy *Biological Abstracts* by breaking it up into its components, but rather to maintain it as an itegral unit while offering the membership of the separate societies many of the advantages which they would have if each society had its own individual abstracting journal.

One thing is already assured. Coverage will be prompt, as also the issue of indexes. This year has proved that. The aim is a lag of no more than two manths, and index in the spring. The extent of coverage must, of course, depend on the extent of support. Biologists can get only what they pay for. With no national society treasury to draw upon, this must be so. At least 1250 subscriptions to the complete edition, and four times as many orders for section issues, are required to make possible publication without deficit. Libraries can be depended on to provide the former. Is it too much to expect an average of 1,000 individual subscribers to each section?

Each of the biological societies concerned is being invited to set up a committee which will be effective in fixing the editorial policies and standards of the *Abstracts* within its respective field.

In order to facilitate the plans for 1939, subscription blanks will be shortly distributed to the entire membership of the Societies constituting the Union as well as to libraries and other institutions far and wide. It is hoped that as many responses as possible may be forwarded by November 1st to the Office of the Business Manager, Biological Abstracts, University of Pennsylvania, Philadelphia, Pennsylvania.

Board of Trustees of *Biological Abstracts*.

SEPTEMBER 20, 1938.

Book Reviews

CRYPTOGAMIC BOTANY. By Gilbert M. Smith. McGraw-Hill Book Co., New York. 1938. Vol. I, Algae and Fungi, viii + 545 pp., 299 figs., $4.00. Vol. II, Bryophytes and Pteridophytes, vii + 380 pp., 224 figs., $3.00.

The great advances made in recent years in our knowledge of cryptogams necessitated a comprehensive treatment suitable to courses in the morphology of these groups. Available works were either too specialized or too antiquated to be of real use in teaching. The difficult task of preparing such a treatment was undertaken by Professor Smith and his labors resulted in the present work for which morphologists will be indebted to him.

The plan of the work is based on the belief that "a thorough knowledge of a representative series in each of the major groups is better than scraps of information about a large number," although the impossibility of meeting all tastes regarding the selection of "types," the space allotted to the different groups, and his phyletic discussions and diagrams is apparent to the author and to all others familiar with the complexity of the problems here concerned, the imperfection of available knowledge, and the large subjective element involved in making phyletic deductions.

In the main, the most recent researches have been included; but in the treatment of Fungi some important contributions were apparently overlooked. There are a number of new groupings found in these volumes, as well as new designations for some of them and also simplifications in terminology, viz., biphasic and triphasic alternation of generations in Florideae for haplo- and diplobiontic resp.

Very refreshing is the use of many well chosen illustrations from recent publications and numerous excellent drawings by the author and his assistants. These original drawings frequently illustrate new "types," mainly American representatives of wide distribution and fairly common occurrence. In this respect as well as in many others the volumes offer much new material.

Unfortunately, the bibliographies appended to the various chapters had to be abbreviated greatly, by the elimination of titles in favor of key words indicating the contents of the articles, in order to save space.

The appearance of the present work leaves morphologists with the wish for an equally well prepared morphology of the seed plants.—TH. JUST.

FERNS OF THE SOUTHEASTERN STATES. By John Kunkel Small. Drawings by Ruth Sinclair George. The Science Press Printing Co., Lancaster, Pa. 1938. ii + 517 pp. $3.50.

Those who were somewhat disappointed at the time of publication of the "Manual of the Southeastern Flora" because the "Ferns" were excluded will be more than compensated by the appearance of the present work. Its author, unfortunately, did not live to see it published. Fittingly the opening pages contain "John Kunkel Small—an Appreciation" by H. Harold Hume bespeaking warmly the character and the achievements of the man whose name will always be associated with the flora of the southeastern States.

The area covered is that "south of the Virginia-Kentucky State line and east of the Mississippi River." Its six major "plant provinces," the "outstanding features" of which are pointed out in the introduction are shown on a map. A "Key to the Orders, Families, and Genera Illustrated for Students" with 100 clear figures follows, while the "Taxonomic Treatment, with Distribution and Notes" comprises the bulk of the book. The 189 full page illustrations are either drawn to natural size or properly reduced and show in most cases the habit of the species together with certain characteristic structures. Their careful execution and beauty contribute greatly to the value of the book. The treatment afforded each species exceeds in extent that ordinarily found in "manuals," and much interesting information, mostly of an ecological nature, is presented in addition to the detailed descriptions, distributional data etc. Besides a number of new combinations necessitated by the author's delimitation of certain genera, several new species are described by the author and R. St. John. The number of "ferns" (a term here used to include the fern-allies) "growing naturally" in this area totals 189 species, more than "fifty per cent of that of the United States and Canada." Appended are data of "General and Restricted Distribution," "General Notes on the Cultivation of Southeastern Ferns" contributed by William A. Knight, a "Taxonomic List, with Citations" and "Authorities cited in this Work" both contributed by John Hendley Barnhart. A Glossary and an Index complete the work.—TH. JUST.

REPRINT-SERIES

(Reprints 1, 2, 3 were issued with volume 2, reprint 4 with volume 3 and reprint 5 with volume 5).

(1) RAFINESQUE, C. S.—Neogenyton. 1825 ..... $ .25

(2) ———The Natural Family of Carexides. 1840 ..... .50

(3) ———Scadiography of 100 Genera of Ombelliferous Plants, etc. 1840 ..... 1.50

(4) ———Monographie des Coquilles Bivalves et Fluviatiles de la Rieviere Ohio. Remarques sur les Rapports Naturels des Genres Viscum, Samolus et Viburnum. A Bruxelles. 1820 ..... 1.50

(5) LECONTE, J. E.—Reprints of Monographs without plates 2.50

With 42 photographic copies of unpublished plates (7x8). ..... Prices on request

———Two extra plates reproduced from originals in New York Botanical Garden ..... Prices on request

PUBLICATIONS

BAILEY, V.—Cave Life of Kentucky. 1933 ..... $ 1.25

CONANT, R.—The Reptiles of Ohio. 1938. Cloth 2.00

FRIZZELL, D. L.—Terminology of Types. 1933 ..... .25

GREENE, E. L.—Pittonia. A Series of Papers Relating to Botany and Botanists. 5 volumes. 1887-1905 ..... 14.00

———Manual of the Botany of the Region of San Francisco Bay. 1894. Bound cloth 2.00

Unbound 1.50

———Flora Franciscana. Part 2. 1895 ..... .75

———Plantae Bakerianae. 1-3. ..... 1.30

———Cybele Columbiana. A Series of Studies in Botany, chiefly North American. (All published). 1914 ..... .75

KISTLER, ELLEN D.—Bibliography of the Botanical Writings of Edward Lee Greene. 1936 ..... .25

LYON, M. W. JR.—Mammals of Indiana. 1936. Cloth 3.00

UTTERBACK, W. I.—The Naiades of Missouri. 1915-1016 ..... 1.50

WEATHERWAX, J.—The Phylogeny of Zea Mays. 1935 ..... .50

The University of Notre Dame

Notre Dame, Indiana, U.S.A.

THE COLLEGE OF ARTS AND LETTERS
THE COLLEGE OF SCIENCE
THE COLLEGE OF ENGINEERING
THE COLLEGE OF COMMERCE
THE COLLEGE OF LAW THE GRADUATE SCHOOL
THE SUMMER SESSION

The University of Notre Dame, the largest boarding school in the world, is located in northern Indiana adjacent to the industrial city of South Bend and eighty-six miles east of Chicago. There are two lakes on the 1,300 acre campus surrounded by beautiful groves, making an ideal setting for the pursuits of the scientist and naturalist.

For a Bulletin or other information, address

THE REGISTRAR - - Notre Dame, Indiana

Publications in Mediaeval Studies

The University of Notre Dame

VOLUME I—The Works of Peter of Poitiers, Master in Theology and Chancellor of Paris (1193-1205). By Phillip S. Moore. Notre Dame: The University Press, 1936. Pp. ix-218. A critical study of the works of "the most faithful pupil of Peter Lombard." Cloth, $2.25; Paper, $1.75.

VOLUME II—Commentarius Cantabrigiensis in epistolas Pauli e schola Petri Abaelardi: 1. In epistolam ad Romanos. By Arthur Landgraf. Critical text and notes. 1937. Cloth, $2.25; Paper, $1.75.

VOLUME III—Petri Pictaviensis allegoriae super tabernaculum Moysi. By Philip S. Moore and James A. Corbett. Notre Dame, 1938. Pp. xxiii-214. Critical text and notes. Cloth, $2.25. Paper, $1.75.

IN PREPARATION—Commentarius Cantabrigiensis in epistolas Pauli e schola Petri Abaelardi: 2. In epistolas ad Corinthios, Galatas, et Ephesios. By Arthur Landgraf. Critical text and notes.

Petri Pictaviensis sententiarum libri quinque. By Philip S. Moore, Marthe Dulong and Joseph N. Garvin. Critical text and notes.

Prepositini cancellarii Parisiensis summa theologica. By Philip S. Moore and Marthe Dulong. Critical text and notes.

Prepositini cancellarii Parisiensis summa contra hereticos. By James A. Corbett and Joseph N. Garvin. Critical text and notes.

ADDRESS: Publications in Mediaeval Studies, The University of Notre Dame, Notre Dame, Indiana (U. S. A.).

The University Press, Notre Dame, Indiana